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SOME PHOTOGRAPHIC RESULTS OF THE  
APOLLO 11 MISSION

By Paul A. Larsen  
Aero-Astrodynamic Laboratory

February 27, 1970

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<p><b>16. ABSTRACT</b></p> <p>The work reported in this document was done for several reasons: (1) to show what types of photographs are available as a result of the Apollo 11 mission; (2) to give the best possible photographic description of the lunar terrain in the vicinity of Tranquillity Base, and as many other areas of the lunar surface as possible, so that Lunar Roving Vehicle (LRV) mission planners, designers, and engineers can obtain a "feel" for several types of lunar terrain that may be encountered by the lunar roving vehicle; (3) to show some of the better pictures as single photographs, stereograms, constructed panoramic views, sequence strips, and mosaics; (4) to demonstrate the feasibility of making certain elevation measurements of lunar topographical features, by using lunar photographs, photogrammetric techniques, and locally available photogrammetric equipment; and (5) to provide a reminder of the value of high altitude earth photography for earth resources studies.</p>			
<p>The 1405 photographs taken during the Apollo 11 mission were reviewed. Of this number, 104 were judged to be of sufficient interest for this study, and to warrant further analysis. Consequently, 27 stereograms, 9 panoramic views, 1 sequence strip, 1 mosaic, and 17 single photographs have been included in this report, together with pertinent interpretations of the photographic data.</p>			
<p>A large number of high quality photographs are available as a result of the Apollo 11 mission. Engineers and designers should find them useful for design of lunar surface vehicles and equipment. Geologists and scientists should find them helpful in</p>			
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confirming existing geological interpretations, in revising certain interpretations that were based on earlier and perhaps insufficient data from earth-based observations, and in making geological interpretations of areas that were not previously analyzed. Cartographers should find the photographs valuable in lunar map production and revision. The use of photogrammetric equipment, available in the Aerospace Environment Division of MSFC's Aero-Astrodynamic Laboratory, was demonstrated to be feasible for measuring elevation differences between various points on vertical lunar photographs, resulting from Apollo missions.

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## DEFINITION OF SYMBOLS

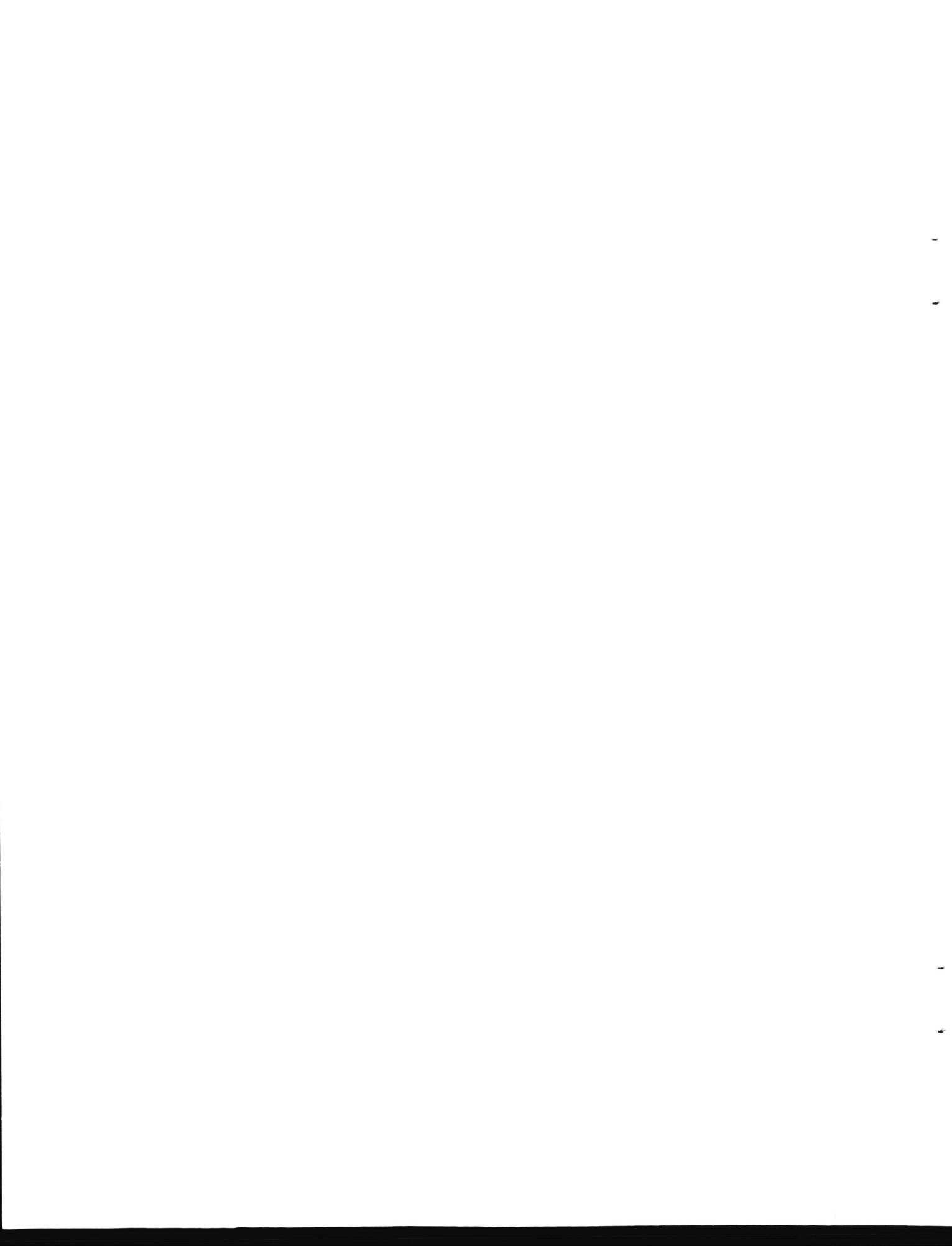
<u>Symbol</u>	<u>Definition</u>
h	elevation of a point above datum
f	focal length of a camera
H	altitude of an aircraft or spacecraft
B	distance between two points in space from which vertical photographs were taken
p	linear parallax of a point at elevation h above datum
t	tilt angle of the camera

## SPECIALIZED TERMS

Forward Overlap	the amount by which one aerial photograph includes the same area covered by another, customarily expressed as a percentage
Parallax	the apparent displacement of the position of a body, with respect to a reference point or system, caused by a shift in the point of observation
Principal Point	the foot of the perpendicular from the camera lens to the photograph
Tilt Angle	the angle between the optical axis of the camera and the vertical

## NONSTANDARD ABBREVIATIONS

CSM	command and service module
LM	lunar module
LRRR	laser ranging retro reflector
LRV	lunar roving vehicle
PSE	passive seismic experiment
TO	target of opportunity



TECHNICAL MEMORANDUM X-64501

SOME PHOTOGRAPHIC RESULTS OF THE APOLLO 11 MISSION

SUMMARY

Photographic coverage of the topographical features in the Tranquillity Base area is provided by means of stereograms and panoramic view constructions. Based upon this coverage, it is concluded that vehicles, such as the lunar roving vehicles currently being studied, can be maneuvered and operated safely and effectively in mare areas similar to the Tranquillity Base area, provided a reasonable amount of driver caution and careful route selection are exercised. Larger scale stereograms of lunar topographical features seen from orbit are included for use in LRV traverse planning and other future lunar surface experiment planning. High altitude earth stereograms presented herein serve as a reminder of the value of such photography in earth resources analyses. Analysis of photographs resulting from future Apollo missions can provide further confidence in LRV designs, and can assist in advancing vehicle operating guidelines. Accordingly, it is recommended that such analyses be conducted.

I. INTRODUCTION

The Apollo program has been the source of many excellent photographs, taken by the astronauts, of the surfaces of the moon and the earth. These photographs are a valuable result of the nation's space efforts, and it is becoming increasingly apparent that the pictures will be studied for many years to come. Typical studies and analyses for which the photographs may be useful are Geological Analyses of the Moon and Earth, Lunar and Earth Cartography, Earth Pollution Studies, Earth Resources Studies, and Military Applications. Section II of this report presents a brief summary of all the photographs taken during the Apollo 11 mission, as a convenient aid to those who desire to obtain photographs for their specific purposes.

The work reported herein deals primarily with lunar terrain, topography, and geography. However, photographic interpretations of some earth pictures are included, to serve as a reminder of the value of the Apollo photography in conducting earth resources analyses. These earth stereograms, together with their photographic interpretations, are located in Section III of this report. Also in Section III are the

stereograms of the lunar surface in general, and of the Tranquillity Base area in particular. Photographic interpretations have been placed immediately preceding each page of stereograms for easy reference while viewing the stereograms. This pattern has been followed throughout the report.

A brief feasibility demonstration of two methods for measuring differences in lunar elevations photogrammetrically, is included in Section IV, together with illustrations of the methods. The purpose of this section was essentially to help prepare for an efficient exploitation of vertical lunar photographs which will eventually become available, and to introduce the method to others who may have a need for making similar measurements.

Section V contains single photographs showing craters and other interesting lunar geological features, in cases where insufficient photographs were available for making stereograms.

Section VI contains eleven views of the lunar surface, each of which was constructed from two or more photographs. Nine of these constructed views provide panoramic coverage of the Tranquillity Base area, and these should prove helpful to LRV designers and other lunar surface experiment planners. A key to the directional orientation of the panoramic views of Tranquillity Base is provided in figure 23. Figure 24 shows the geographical location of the Apollo 11 landing site, Tranquillity Base.

Apollo 11, manned by astronauts Neil A. Armstrong, Michael Collins, and Edwin E. Aldrin, was launched from Cape Kennedy on July 16, 1969, at 13:32:01 Greenwich mean time. The lunar module "Eagle" landed on the moon 102 hours, 45 minutes, and 40 seconds after launch. Twenty-one hours and 36 minutes later, ascent from the lunar surface began, and splashdown in the Pacific Ocean occurred 195 hours, 18 minutes, and 35 seconds after launch.

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## II. DESCRIPTIVE SUMMARY OF AVAILABLE PHOTOGRAPHS

For background information, and as a help to those who may want to use Apollo 11 photographs for their own specific purposes, the contents of the 9 magazines, exposed on the Apollo 11 mission, are described below. This information is extracted from reference 2.

Magazine N, frame numbers AS-11-36-5291 through 5432 (in color), provides coverage of the mission's translunar phase, earth pictures, capsule interior views, and operational photographs. Lunar surface objects shown were craters IX, 204, 205, 207, 211, 216, 217, 220, 275, 282, 292, and targets of opportunity 30, 34, 46, and 50.

Magazine R, frame numbers AS-11-37-5433 through 5555 (in color), contains pictures taken from orbital altitude over the lunar surface, as well as lunar surface pictures taken from the LM at Tranquillity Base. Targets of Opportunity 67 and 115 were covered in the orbital pictures. An 80 mm lens was used for all photographs taken in magazine R.

Magazine "O", frame numbers AS-11-38-5556 through 5733 (black and white) contains photographs of the lunar farside, the Sea of Fertility, and Target of Opportunity 137. A 250 mm lens was used.

Magazine "Q", frame numbers AS-11-39-5737 through 5843 (black and white), contains photography of the Tranquillity Base area. An 80 mm lens and a 60 mm lens with reseau images were used.

Magazine "S", frame numbers AS-11-40-5844 through 5970 (color), contains pictures taken on the lunar surface at Tranquillity Base. Pictures of the astronauts, the lunar module, experiment packages, and the lunar horizon are included. A 60 mm lens was used.

Magazine "P", frame numbers AS-11-41-5971 through 6159 (black and white), contains photographs of the lunar surface taken from the command module at an altitude of 60 nautical miles. An 80 mm lens was used to record targets of opportunity 34, 67, 80, 84, and 115. A 250 mm lens was used to photograph targets of opportunity 15, 80, 132, and crater 208.

Magazine "U", frame numbers AS-11-42-6160 through 6348 (black and white), contains pictures of the lunar nearside and farside, and the solar corona. Targets of opportunity photographed were 11, 16a, 33, 43, 46, 66, and 67. Both 80 mm and 250 mm lenses were used.

Magazine "T", frame numbers AS-11-43-6349 through 6539 (black and white), contains photographs of the lunar surface from 108 degrees east longitude to 100 degrees east longitude, taken through a 250 mm lens, which covered targets of opportunity 53 and 55. An oblique sequence starting at 160 degrees west longitude and continuing to 60 degrees east longitude, using a 250 mm lens, provided coverage of targets of opportunity 11, 16, 30, 34, 66, and 67. In addition, targets of opportunity 33 and 46 were photographed using an 80 mm lens.

Magazine "V", frame numbers AS-11-44-6540 through 6696 (in color), contains lunar topography pictures, pictures of earth before CSM splashdown, and targets of opportunity 15, 35, 36, 43, 46, 47, 50, 53, 55, 57, 61, and 80.

Prints of these photographs may be ordered through the MSFC Photo Laboratory, or the NASA Space Science Data Center, Goddard Space Flight Center, Greenbelt, Maryland, 20771.

### III. STEREOGRAMS OF THE EARTH AND THE MOON

Twenty-seven stereograms were prepared, based upon the Apollo 11 photographs described in Section II. The photograph frame numbers of each stereo pair, together with an interpretation of each stereogram's contents, are provided. The stereograms which are marked with an asterisk are included in this report as figures 1-A through 14. Those which are listed and discussed, but not marked with an asterisk, are not included in the report since the stereo qualities of the pair were judged to be mediocre. It should be pointed out that the photographic interpretations presented herein were accomplished by the author, using 8 x 10-inch photographs. Obviously, with the much smaller photographs used in this report, and the resultant loss of definition due to reproduction, some of the described features may be difficult to observe or locate.

When viewing the stereograms, it is suggested that the reader use a "pocket stereoscope" which is readily available from suppliers such as (1) Abrams Instrument Corporation, 606 E. Shiawassee Street, Lansing, Michigan, 48901; (2) North American Technological Operations, P. O. Box 1012, Pittsfield, Massachusetts, 01201; or (3) Air Photo Supply Corporation, Yonkers, New York, 10705. With some practice, certain individuals are able to observe a stereo model (the tridimensional image observed by viewing a stereo pair) by indirect stereoscopic perception, using the naked eye and a small card placed vertically between the two photos to separate them.

STEREOGRAMS CONSTRUCTED FROM APOLLO 11 PHOTOGRAPHS

Stereo Pair Frame Nos.: 5303/5302\* (Figure 1-A)

Film Type: Color S.O. 368

Subject: This is an excellent view of Northwestern United States and British Columbia, Alberta, Saskatchewan, and Manitoba in Canada; Vancouver Island is visible, as is Mt. Olympus in Olympic National Park, Washington. Inland bodies of water clearly visible are Great Salt Lake and Utah Lake in Utah; Pyramid Lake and Walker Lake in Nevada; Lake Tahoe, southwest of Reno, Nevada; Columbia and Snake Rivers in Washington, and Lake Manitoba and portions of Lake Winnipeg in Manitoba, Canada. The Sacajawea Peak in Oregon, east of the Columbia Plateau, is visible as are mountain ranges Wasatch in Utah, Sierra Nevada in California, Cascade in Oregon and Washington, Clearwater Mountains and Bitterroot Range in Idaho, and Wind River Range and Bighorn Mountains in Wyoming. The western coastline visible in the photographs extends from just north of San Francisco to Princess Royal Island in British Columbia.

Stereo Pair Frame Nos.: 5305/5306\* (Figure 1-B)

Film Type: Color S.O. 368

Subject: This view shows Mexico and the Baja and the Yucatan peninsulas. The Gulf of Mexico, Gulf of Tehuantepec (south of lower end of Mexico), and the Gulf of California (east of Baja peninsula), and White Sands National Monument, just to the east of the Rio Grande. In addition to the Rio Grande, portions of the Canadian River in Oklahoma, and the Red River, between Oklahoma and Texas are just barely visible. The Sacramento mountains east of White Sands and, in Mexico, the Sierra Madre Occidental, Sierra Madre Oriental, and Sierra Madre del Sur mountain ranges can be seen.

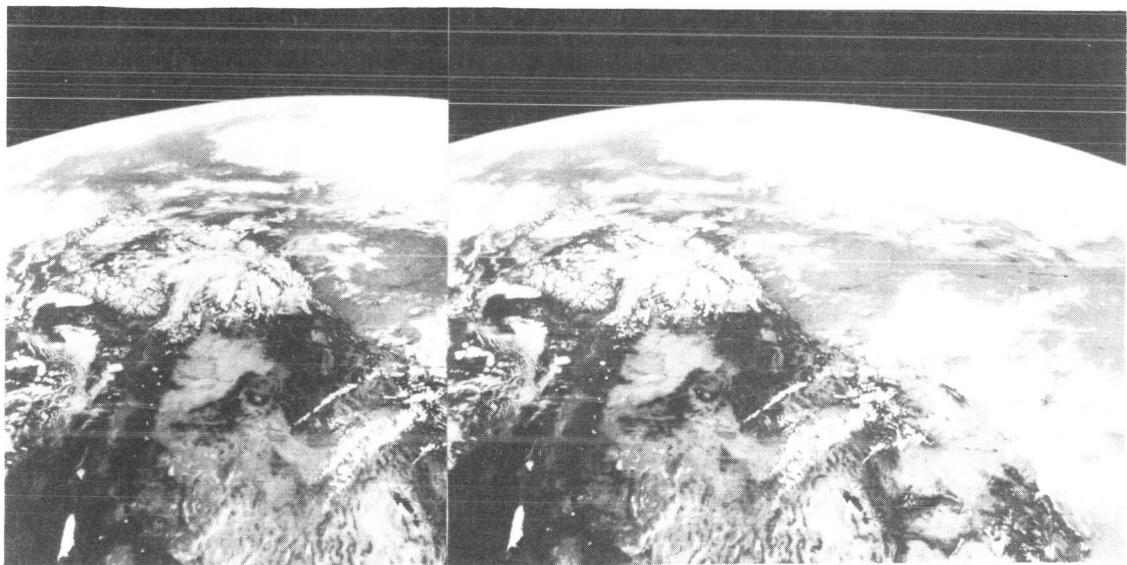


FIG. 1-A. 5303/5302: NORTHWESTERN U.S.  
AND CANADA.

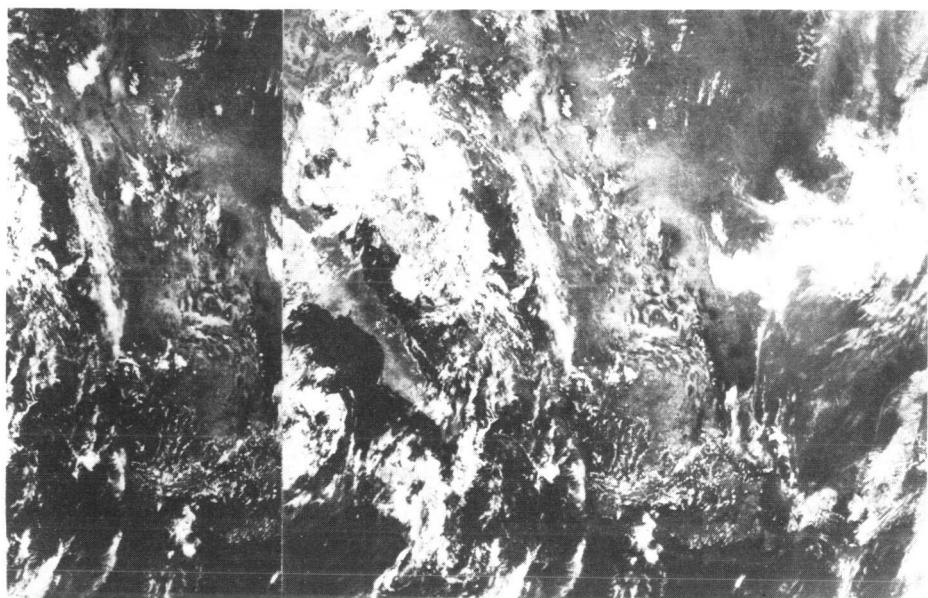


FIG. 1-B. 5305/5306: SOUTHWESTERN U.S. AND  
MEXICO.

Stereo Pair Frame Nos.: 5323/5324\* (Figure 2-A)

Film Type: Color S.O. 368

Subject: This stereogram of the northern hemisphere shows the Great Lakes, Chesapeake Bay, Cape Cod, Greenland, part of the Arctic Ocean, Spain, and the Mediterranean Sea.

Stereo Pair Frame Nos.: 5338/5339

Film Type: Color S.O. 368

Subject: The western part of U. S., Mexico, and parts of Central America are seen in these photographs, as well as the Sierra Nevada Range in California and the Cascade Range in Oregon and Washington. Hawaii (an island built by the coalescence of lava from five large shield volcanoes) is just barely discernible through a hole in the clouds in approximately the center of the pictures.

Stereo Pair Frame Nos.: 5352/5353\* (Figure 2-B)

Film Type: Color S.O. 368

Subject: This is an excellent stereo pair showing Africa, Madagascar, Saudi Arabia, Iran, Afghanistan, a small portion of the USSR between the Caspian Sea and Lake Aral, Pakistan, Italy, Spain, and India (barely visible under the clouds). The Red Sea, the Gulf of Aden, the Persian Gulf, the Gulf of Oman, the Mediterranean Sea, the Black Sea, the Caspian Sea, Lake Aral, the Arabian Sea, and the Indian Ocean are all visible. In southern Libya and northern Chad, a "U-shaped" mountain range is visible; the opening in the "U" points toward the Qattara Depression (elevation - 436 feet) in the northern part of the United Arab Republic.

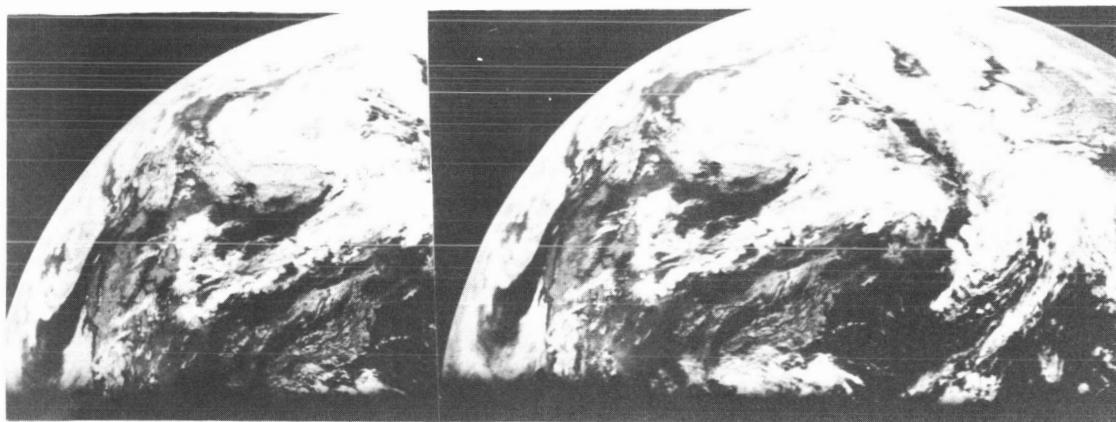


FIG. 2-A. 5323/5324: NORTHERN HEMISPHERE.

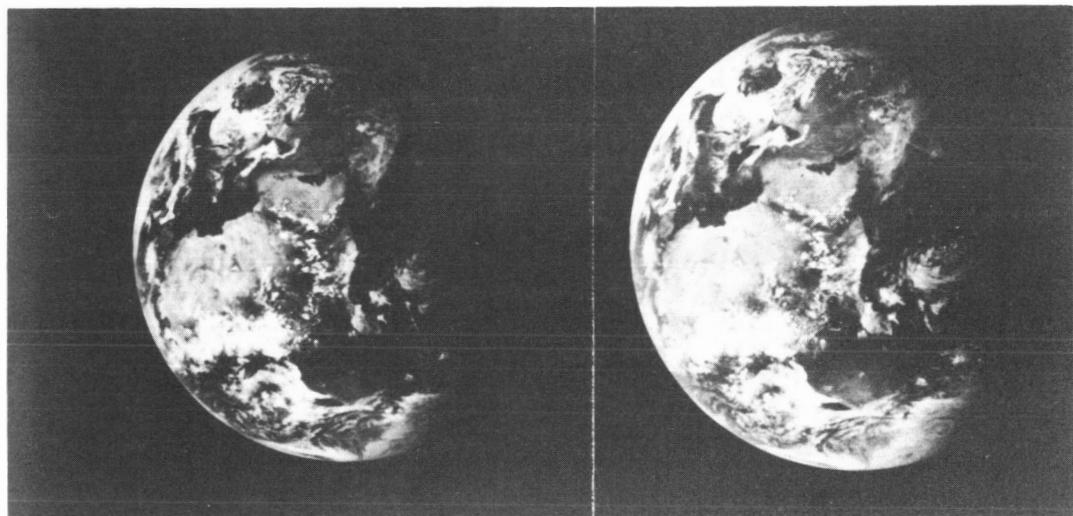


FIG. 2-B. 5352/5353: NORTH  
AFRICA AND SOUTHERN  
EUROPE.

Stereo Pair Frame Nos.: 5367/5366\* (Figure 3-A)

Film Type: Color S.O. 368

Subject: This is a fairly good view of North and South America.

Stereo Pair Frame Nos.: 5453/5459

Film Type: Color S.O. 368

Principal Point: Latitude - 0.67°N  
Longitude - 23.49°E

Sun Angle: Low

Subject: A shallow crater, SSW from the LM and in the LM's shadow, is visible.

Stereo Pair Frame Nos.: 5512/5511\* (Figure 3-B)

Film Type: Color S.O. 368

Principal Point: Latitude - 0.67°N  
Longitude - 23.49°E

Sun Angle: Low

Subject: Shown here is a ray of coarse blocks north of the LM, with the flag and TV camera in the foreground.

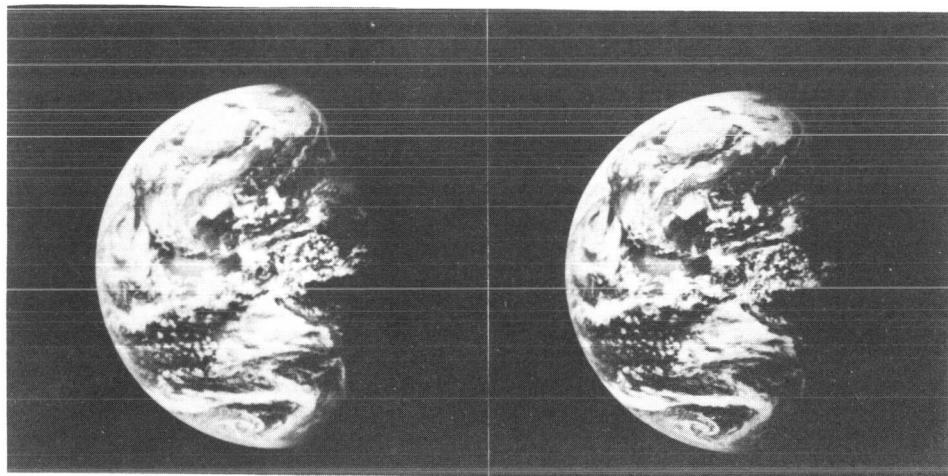


FIG. 3-A. 5367/5366: NORTH AND SOUTH AMERICA.

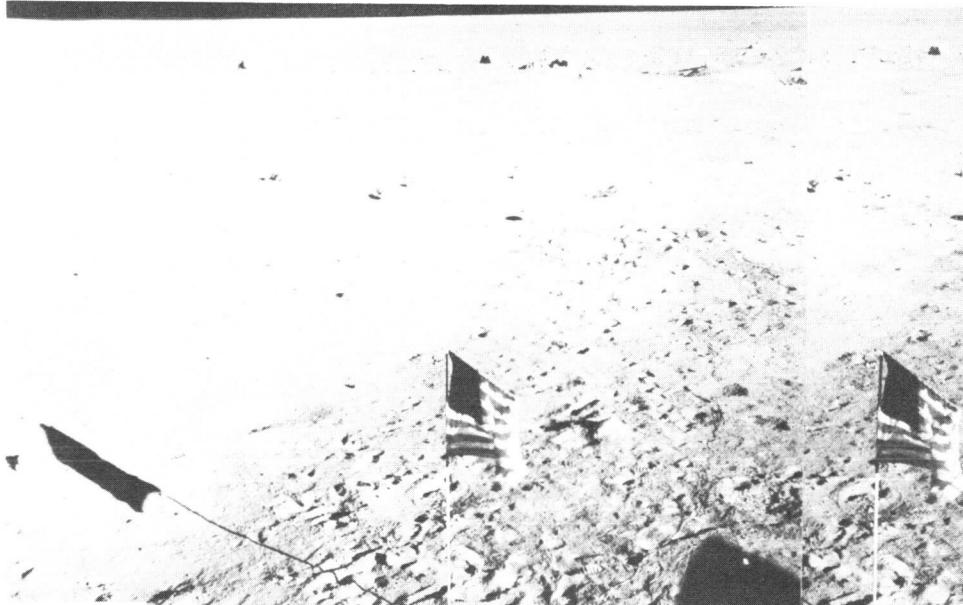


FIG. 3-B. 5512/5511: TRANQUILLITY BASE - NORTH.

Stereo Pair Frame Nos.: 5516/5517\* (Figure 4-A)

Film Type: Color S.O. 368

Principal Point: Latitude - 0.67°N  
Longitude - 23.49°E

Sun Angle: Low

Subject: This view is similar to the preceding stereo pair, but includes LM thruster as well.

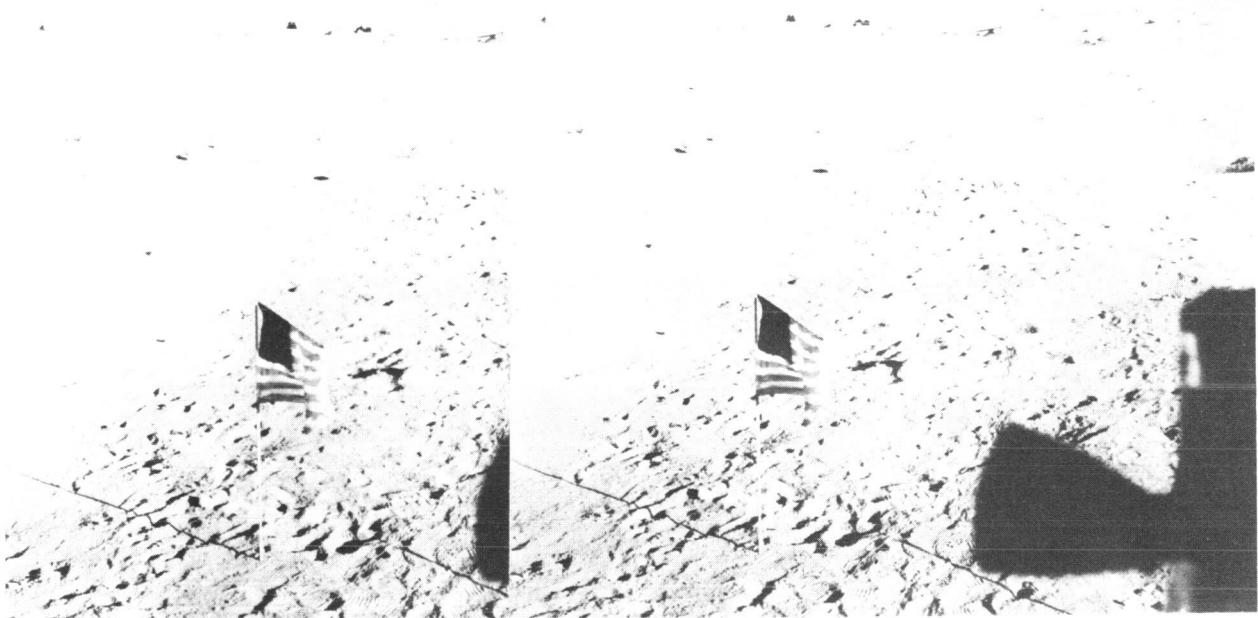
Stereo Pair Frame Nos.: 5550/5548\* (Figure 4-B)

Film Type: Color S.O. 368

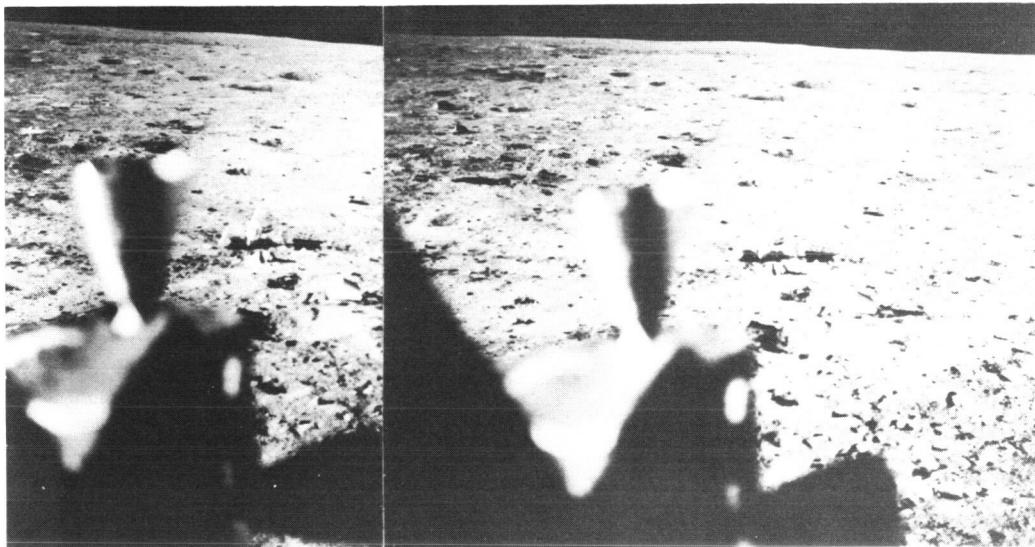
Principal Point: Latitude - 0.67°N  
Longitude - 23.49°E

Sun Angle: Low

Subject: This is a view looking south from the LM toward the Laser Ranging Retro-Reflector (LRRR) and Passive Seismic Experiment (PSE); LM thrusters are also visible.



**FIG. 4-A. 5516/5517: TRANQUILLITY BASE - NORTH.**



**FIG. 4-B. 5550/5548: TRANQUILLITY BASE - SOUTH.**

Stereo Pair Frame Nos.: 5563/5562\* (Figure 5-A)

Film Type: Black and White - 3400

Principal Point: Latitude - 7.0°S  
Longitude - 178.5°E

Sun Angle: Medium

Subject: Shown here is Crater 308, an old crater, probably Pre-Eratosthenian, with an eroded rim and evidence of slumping at the base of the wall. The southern portion is shown (see also figure 33).

Stereo Pair Frame Nos.: 5590/5591\* (Figure 5-B)

Film Type: Black and White - 3400

Principal Point: Latitude - 4.0°S  
Longitude - 151.0°E

Sun Angle: Medium

Subject: This is a small fresh bright Copernican crater on the northeast rim of crater 297. Crater 297's diameter is approximately 65 nautical miles (reference 3).

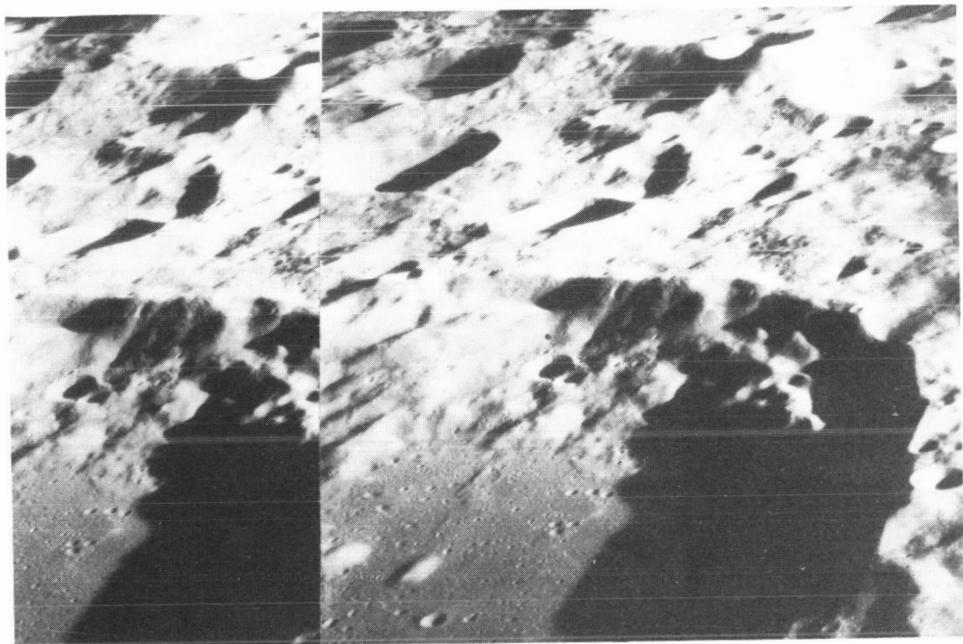


FIG. 5-A. 5563/5562: CRATER 308.

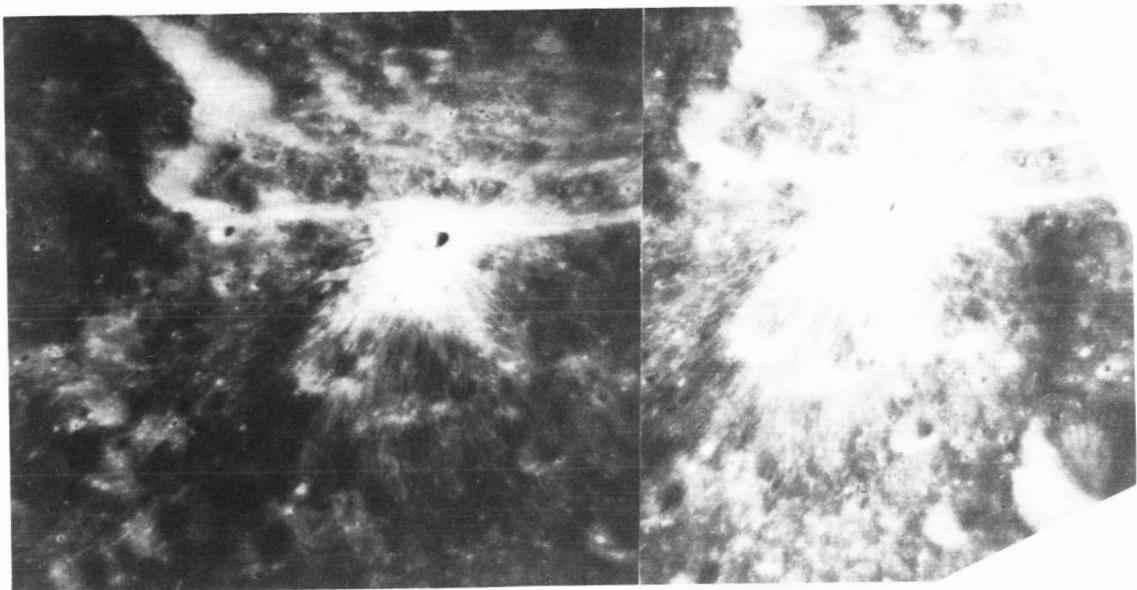


FIG. 5-B. 5590/5591:  
CRATER 297.

Stereo Pair Frame Nos.: 5594/5593\* (Figure 6-A)

Film Type: Black and White - 3400

Principal Point: Latitude -  $1.5^{\circ}$ S  
Longitude -  $139.5^{\circ}$ E

Sun Angle: Medium

Subject: Shown here are two impact craters about 50 n.mi. north-north-west of crater 292's center. The large one is about 7 n.mi. wide, and the smaller one about 5 n.mi. wide.

Stereo Pair Frame Nos.: 5652/5653

Film Type: Black and White - 3400

Subject: This photo of the moon taken during trans-earth coast is oriented such that the lunar north pole is pointed to the right and down about 30 degrees. Mare Crisium is the dark area on the right, containing Crater Picard, the largest crater visible near the "top." Mare Fecunditatis is in the top center of the photo, with the large bright crater Langrenus, and above it Goclenius (elevation - 6,100 ft), and to its right Rima Goclenius I and Rima Goclenius II. The Pyrenees Mountains, at the "bottom" of Mare Nectaris are visible just "above" Mare Fecunditatis. Also in Mare Fecunditatis (top center of photo) can be seen the crater pair Messier and W. H. Pickering, well known because of the peculiar ray system extending westward from W. H. Pickering, which gives the appearance of a comet's tail. Possibly the crater was formed by a meteor that came in at a sharp angle, splashing matter mainly in one direction.

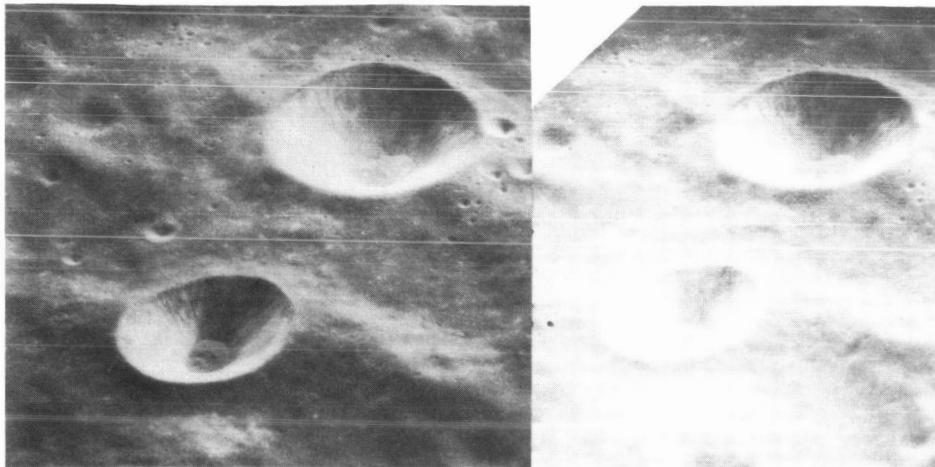
Stereo Pair Frame Nos.: 5745/5744\* (Figure 6-B)

Film Type: Black and White - 3400

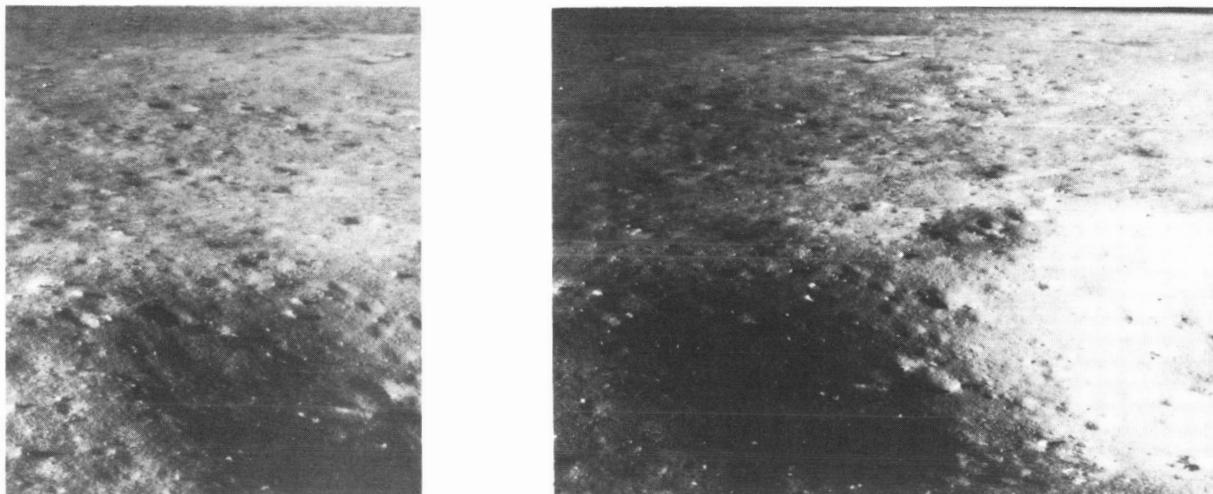
Principal Point: Latitude -  $0.67^{\circ}$ N  
Longitude -  $23.49^{\circ}$ E

Sun Angle: Low

Subject: This is a picture of the lunar surface taken from the LM. "Tombstone Rock" is visible a short distance beyond the crater in the foreground. This photo was taken looking southwest from the LM.



*FIG. 6-A. 5594/5593:  
IMPACT CRATERS  
NEAR CRATER 292.*



*FIG. 6-B. 5745/5744: TRANQUILLITY  
BASE - SOUTHWEST.*

Stereo Pair Frame Nos.: 5757/5756\* (Figure 7-A)

Film Type: Black and White - 3400

Principal Point: Latitude - 0.67°N  
Longitude - 23.49°E

Sun Angle: Low

Subject: This is a view looking south-southwest from the LM into a small crater.

Stereo Pair Frame Nos.: 5768/5767\* (Figure 7-B)

Film Type: Black and White - 3400

Principal Point: Latitude - 0.67°N  
Longitude - 23.49°E

Sun Angle: Low

Subject: A view to the north from the LM towards a rock field is shown here.

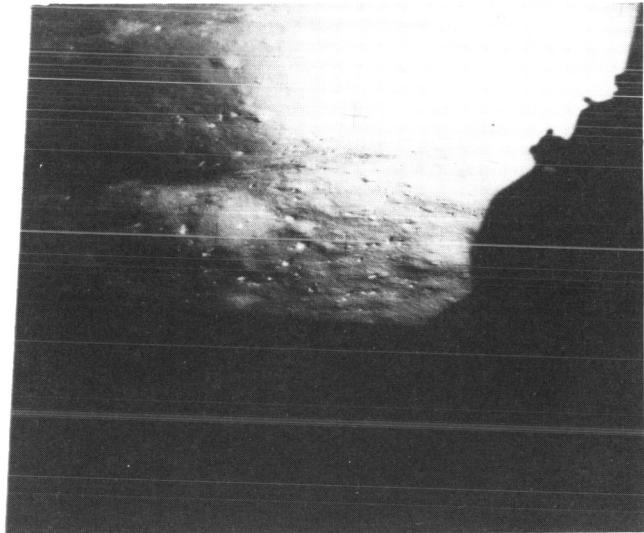
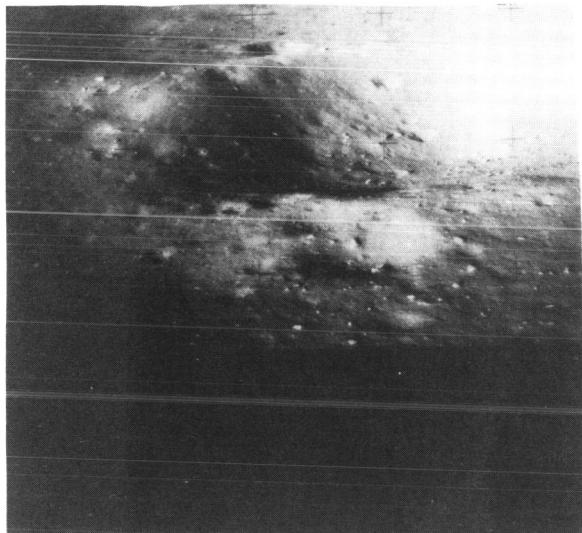


FIG. 7-A. 5757/5756: TRANQUILLITY  
BASE - SOUTH SOUTHWEST.

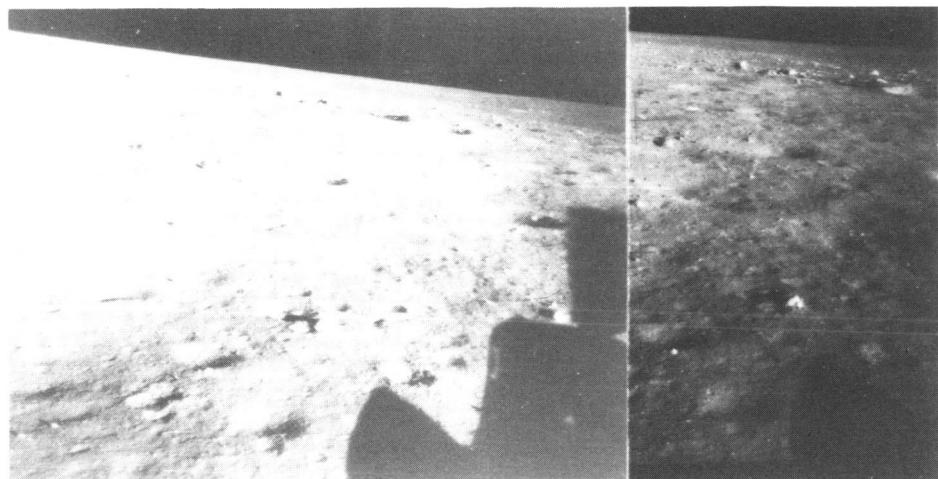


FIG. 7-B. 5768/5767: ROCKFIELD  
NEAR TRANQUILLITY BASE.

Stereo Pair Frame Nos.: 5798/5800\* (Figure 8-A)

Film Type: Black and White - 3400

Principal Point: Latitude - 0.67°N  
Longitude - 23.49°E

Sun Angle: Low

Subject: This stereo pair was included to give a qualitative idea of lunar soil mechanics as indicated by the many bootprints. The LM shadow is in the foreground.

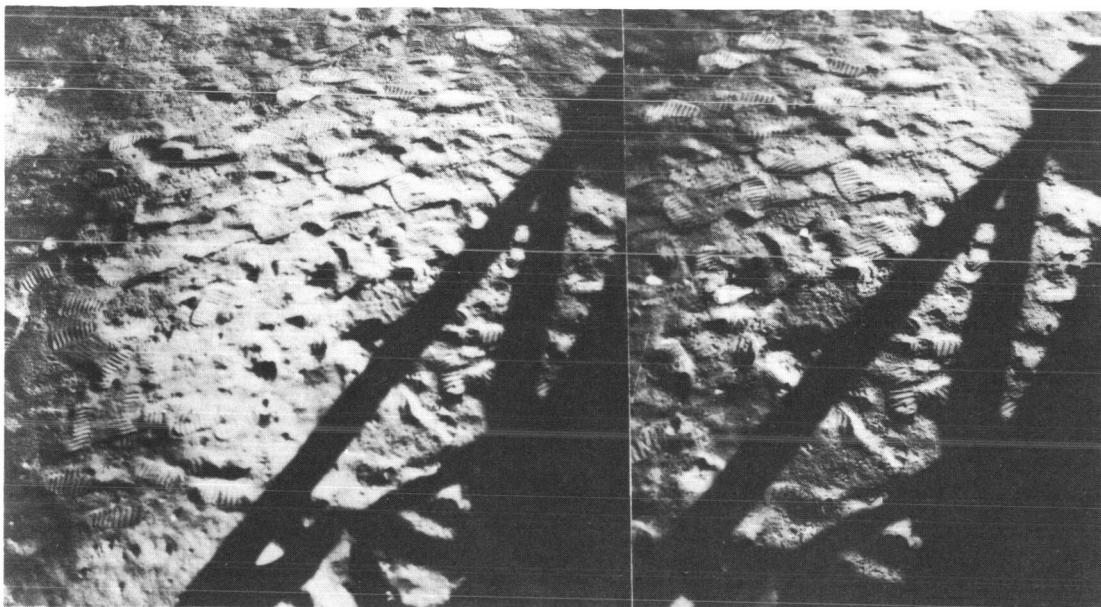
Stereo Pair Frame Nos.: 5860/5859\* (Figure 8-B)

Film Type: Color S.O. 368

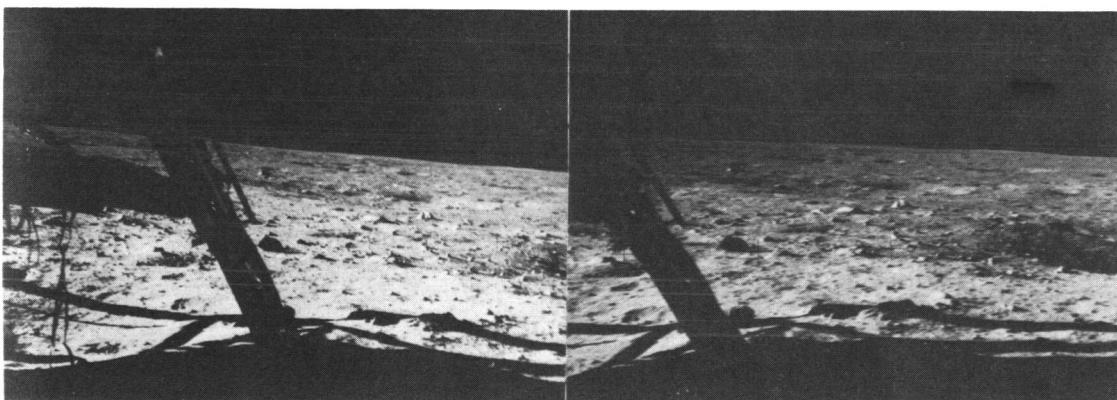
Principal Point: Latitude - 0.67°N  
Longitude - 23.49°E

Sun Angle: Medium

Subject: The lunar terrain looking southeast from LM is shown here.



**FIG. 8-A. 5798/5800: BOOTPRINTS.**



**FIG. 8-B. 5860/5859: TRANQUILLITY  
BASE - SOUTHEAST.**

Stereo Pair Frame Nos.: 5937/5938\* (Figure 9-A)

Film Type: Color S.O. 368

Principal Point: Latitude - 0.67°N  
Longitude - 23.49°E

Sun Angle: Medium

Subject: The terrain, looking south from a point 20 meters to the southeast of the LM, is shown here.

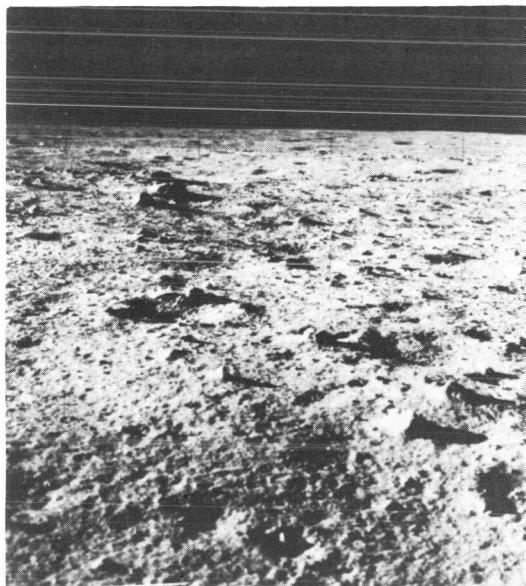
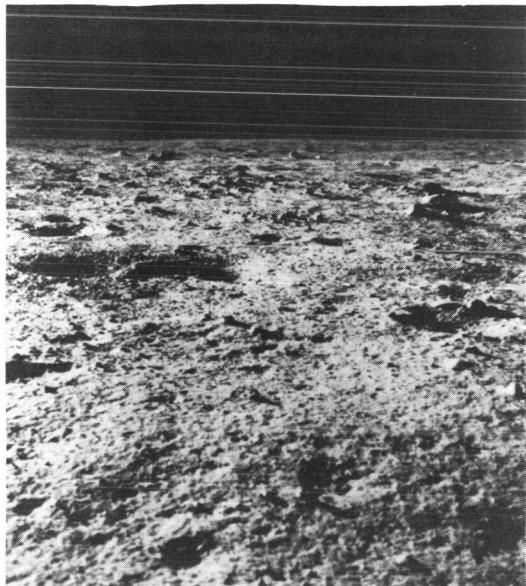
Stereo Pair Frame Nos.: 5956/5954\* (Figure 9-B)

Film Type: Color S.O. 368

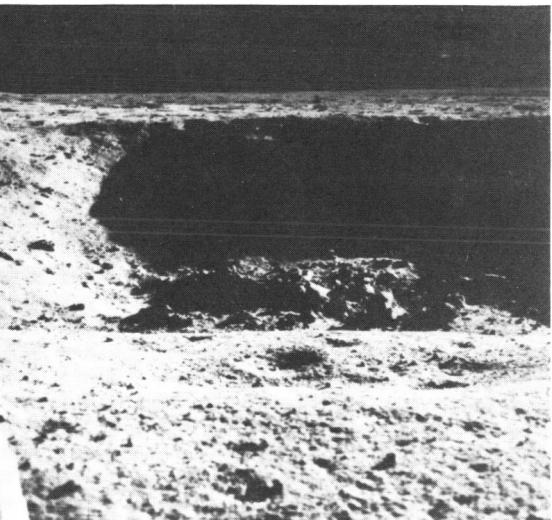
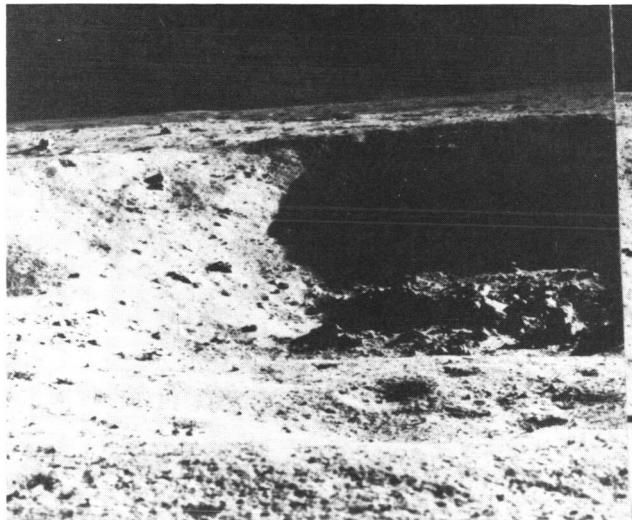
Principal Point: Latitude - 0.67°N  
Longitude - 23.49°E

Sun Angle: Medium

Subject: This small crater with a rocky bottom was photographed from a point 60 meters from the LM, looking northeast. This is not a high quality stereo pair; i.e., its stereo qualities are not the best. However, the two photos were arranged geometrically to optimize the stereo qualities of the rock formations on the crater floor. In the foreground of photo 5954, one can see the stereo close-up camera designed by Eastman Kodak Company, for making close-up stereo photos of lunar surface features.



**FIG. 9-A. 5937/5938: AREA  
SOUTH OF TRANQUILLITY  
BASE.**



**FIG. 9-B. 5956/5954: ROCKY CRATER FLOOR  
NEAR TRANQUILLITY BASE.**

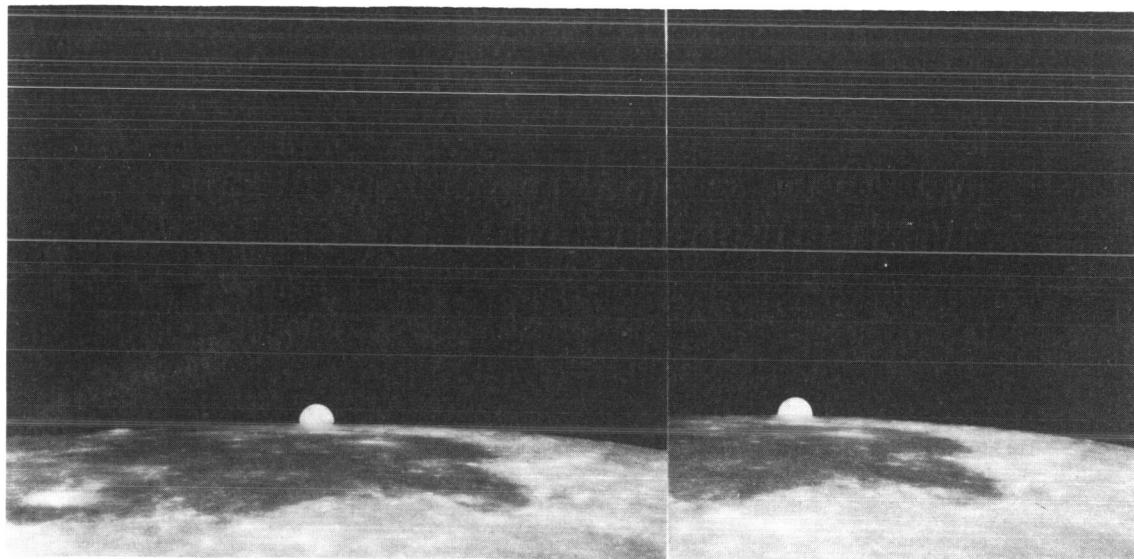
Stereo Pair Frame Nos.: 6019/6018\* (Figure 10-A)  
Film Type: Black and White - 3400  
Principal Point: Above horizon. Sun Angle: High  
Subject: Looking west over Mare Symthii (90°E longitude on the equator), crater 189 can be seen in the lower right-hand corner of the stereo pair.

Stereo Pair Frame Nos.: 6068/6069  
Film Type: Black and White - 3400  
Principal Point: Above horizon. Sun Angle: High  
Subject: Looking west over Mare Fecunditatis, the crater pair Messier and Pickering are clearly visible. The Pyrenees Mountains, dividing Mare Fecunditatis and Mare Nectaris, are just barely visible in the left background.

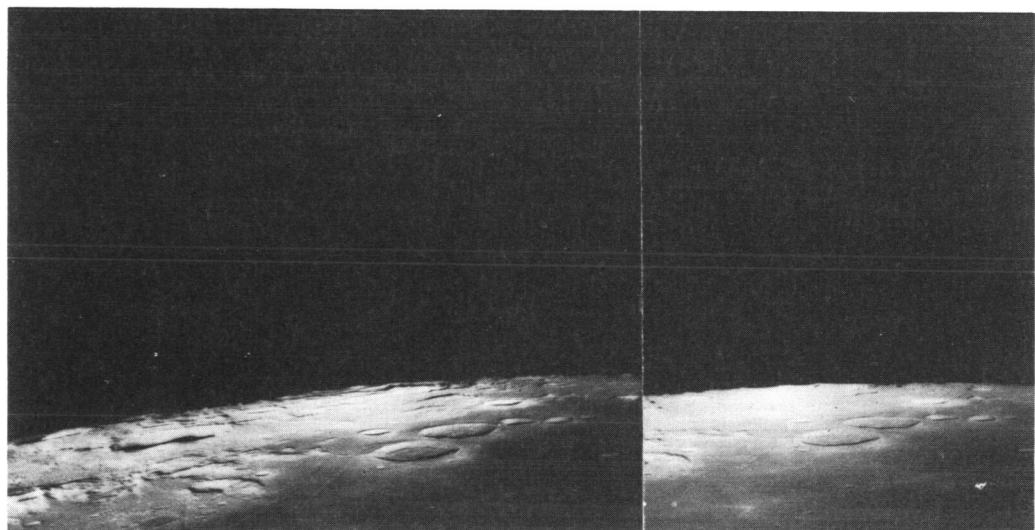
Stereo Pair Frame Nos.: 6084/6085  
Film Type: Black and White - 3400  
Principal Point: Above horizon. Sun Angle: High  
Subject: Looking west over the mare area between Mare Nectaris and Mare Tranquillitatis, Maskelyne B is shown in lower right-hand corner of the stereo pair. Rough, irregular terrain, dotted by many small craters, is visible in the foreground.

Stereo Pair Frame Nos.: 6093/6092\* (Figure 10-B)  
Film Type: Black and White - 3400  
Principal Point: Above horizon. Sun Angle: Medium  
Subject: This stereo pair of the western reaches of Mare Tranquillitatis, provides good stereographic coverage of Crater Delambre (largest crater to left of center); Craters Sabine, Ritter, Ritter B, Ritter D (cluster of four craters to right of center); and Crater Dionysius (a bright, sharp rimmed crater just beyond Sabine and Ritter). Hypatia Rilles are visible in the foreground leading up to Sabine.

Stereo Pair Frame Nos.: 6122/6121  
Film Type: Black and White - 3400  
Principal Point: Latitude - 1.0°N Sun Angle: Low  
Longitude - 18.0°E  
Subject: Shown here is a close-up of Sabine and Ritter, with a mountainous area in the background which parallels Ariadaeus Rille.



**FIG. 10-A. 6019/6018:  
MARE SMYTHII.**



**FIG. 10-B. 6093/6092: WESTERN  
MARE TRANQUILLITATIS.**

Stereo Pair Frame Nos.: 6223/6221\* (Figure 11-A)

Film Type: Black and White - 3400

Principal Point: Latitude - 15.0°N  
Longitude - 57.5°E

Sun Angle: Medium

Subject: This is a good view of the western half of Mare Crisium, showing the craters Yerkes, Lick, and Picard, just above the center of the photograph. Yerkes and Lick have dull rims, and are therefore quite old, probably pre-Eratosthenian in age. Crater Yerkes, the most distant of the three, has a diameter of about 20 nautical miles. This stereo pair is arranged to optimize the geological features (terracing and inner walls) on the southwest boundary of Mare Crisium.

Stereo Pair Frame Nos.: 6305/6304\* (Figure 11-B)

Film Type: Black and White - 3400

Principal Point: Latitude - 1.5°S  
Longitude - 47.5°E

Sun Angle: Medium

Subject: An excellent stereo pair of Messier and Messier A (also known as W. H. Pickering) is seen here. These photos are arranged as if one were viewing the craters from the north-northwest. Rocky, hummocky deposits in the floor of Messier A are visible.

Stereo Pair Frame Nos.: 6309/6310

Film Type: Black and White - 3400

Principal Point: Latitude - 0.5°N  
Longitude - 42.0°E

Sun Angle: Medium

Subject: The area south of Secchi U, showing rilles and chair craters, is visible in this pair.

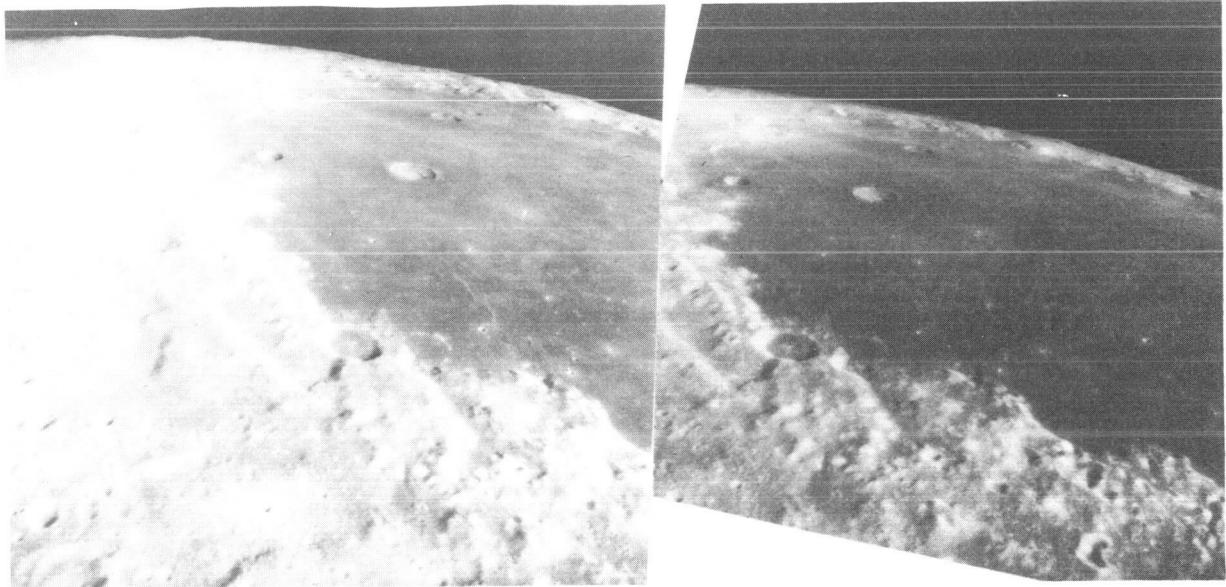


FIG. 11-A. 6223/6221: WESTERN  
MARE CRISIUM.

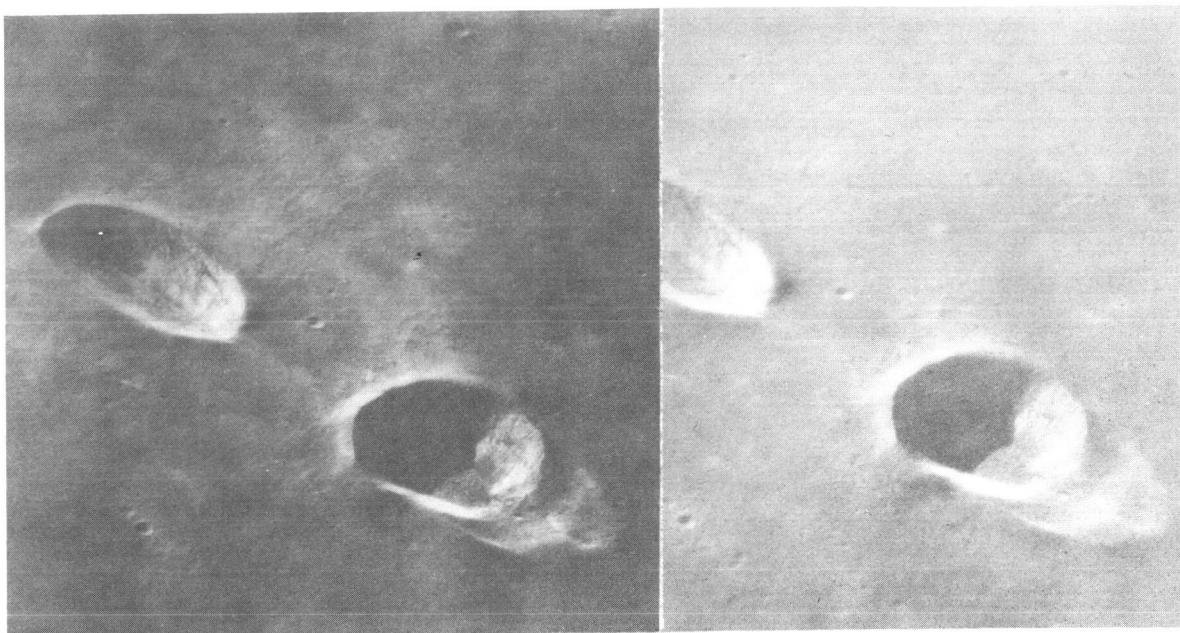


FIG. 11-B. 6305/6304: CRATERS  
MESSIER AND MESSIER A.

Stereo Pair Frame Nos.: 6312/6311\* (Figure 12-A)

Film Type: Black and White - 3400

Principal Point: Latitude - 11.0°S  
Longitude - 46.0°E

Sun Angle: Low

Subject: This view, looking from the northwest, shows crater Gutenberg E, with a dome in its floor, topped by a small Copernican crater; Crater Goclenius in the photograph's center, and off to the southeast, craters Magelhaens and Magelhaens A. Notice the three rilles going from Gutenberg E to Goclenius.

Stereo Pair Frame Nos.: 6395/6396

Film Type: Black and White - 3400

Principal Point: Latitude - 4.5°N  
Longitude - 177.0°W

Sun Angle: Medium

Subject: A portion of the mountainous terrain on the lunar farside west of crater 229 is shown.

Stereo Pair Frame Nos.: 6431/6429\* (Figure 12-B)

Film Type: Black and White - 3400

Principal Point: Latitude - 4.5°N  
Longitude - 142.0°E

Sun Angle: High

Subject: Shown here is a bright impact crater in "IX", a large basin (≈ 160 n.mi. diameter), surrounded by pitted plains.

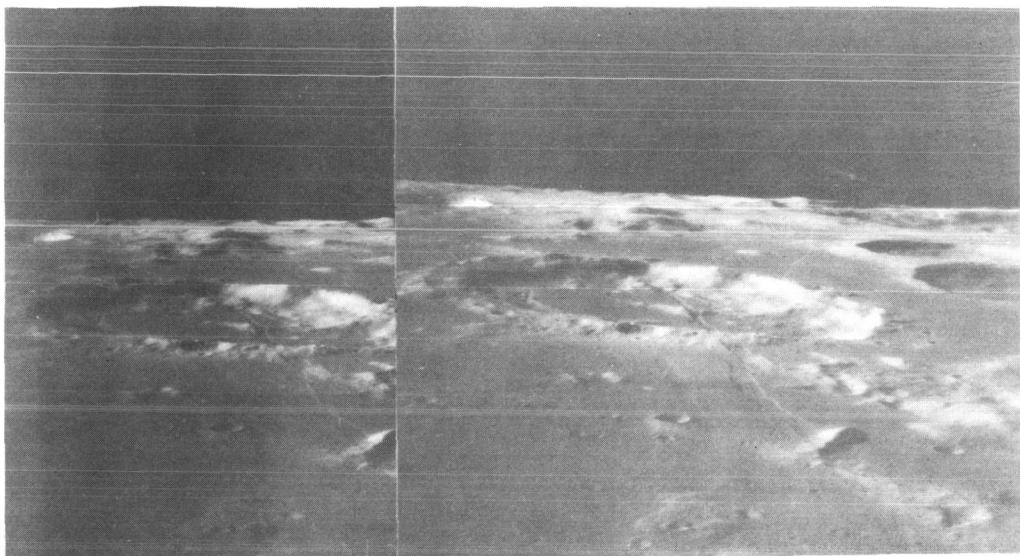


FIG. 12-A. 6312/6311: CRATERS GUTENBERG  
E AND GOCLENIUS.

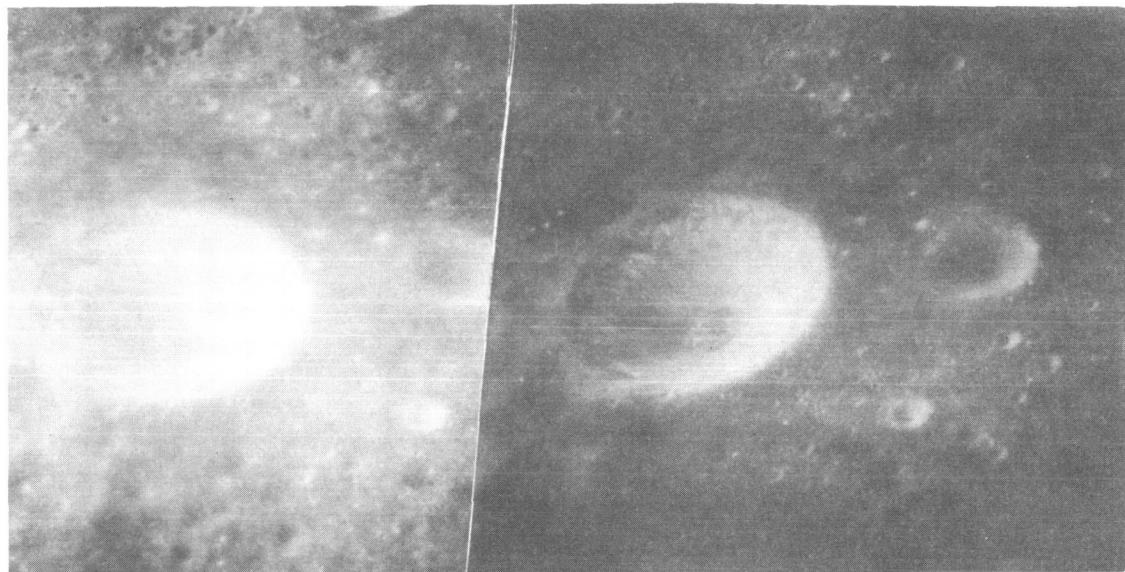


FIG. 12-B. 6431/6429: IMPACT CRATER IN  
CRATER "IX".

Stereo Pair Frame Nos.: 6465/6464\* (Figure 13-A)

Film Type: Black and White - 3400

Principal Point: Latitude - 6.0°N  
Longitude - 79.5°E

Sun Angle: High

Subject: This crater, approximately 6.2 n.mi. in diameter (west to east axis), lies on the western rim of crater Banachiewicz. One can observe a terrace on the western edge of the floor, apparently caused by slumping of the wall material. Also, one can see a patch of lighter colored, more reflective material, rays of which seem to extend downward toward the crater floor. The floor itself appears to be quite hummocky. A delicate, sharp-rimmed structure is quite prominent on the right (eastern) rim of the crater.

Stereo Pair Frame Nos.: 6507/6508

Film Type: Black and White - 3400

Principal Point: Latitude - 1.0°N  
Longitude - 144.5°E

Sun Angle: High

Subject: This old eroded crater, shaped somewhat like a square, is located on the southeast edge of the Crater IX, whose diameter is approximately 160 n.mi., and the crater shown in the stereo pair is approximately 23 n.mi. in the north to south dimension.

Stereo Pair Frame Nos.: 6513/6514\* (Figure 13-B)

Film Type: Black and White - 3400

Principal Point: Latitude - 1.5°N  
Longitude - 137.0°E

Sun Angle: High

Subject: This interesting view, looking west-northwest from the coordinates given, was taken from a point just south of "Crater IX" discussed above. This stereo pair gives a comparison of crater ages. The crater with the prominent dome structure in its floor is designated 216. (Some of the larger domes in lunar craters are visible from earth, and they have been compared with smooth, relatively low-domed structures of volcanic origin on earth.) Craters 216 and 217 (217 is toward the camera from 216) are "medium-aged" or "Eratosthenian." The two relatively small sharp impact craters, near the center of the stereo pair, and the bright small crater in the right foreground, are relatively "new," or "Copernican." Crater 217 is approximately 30 n.mi. in diameter.

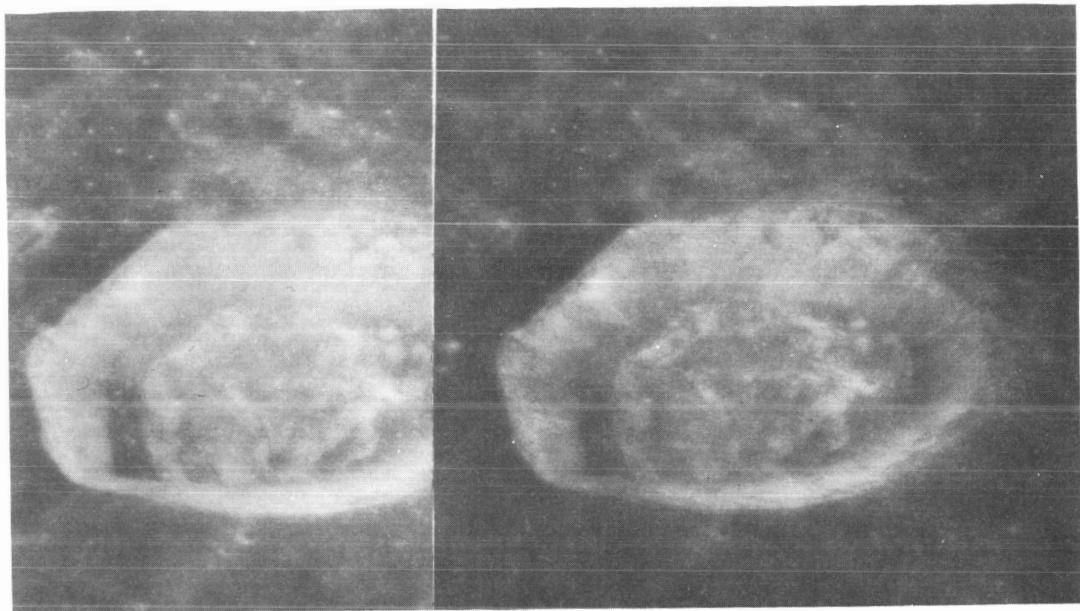


FIG. 13-A. 6465/6464: RIM OF CRATER BANACHIEWICZ.

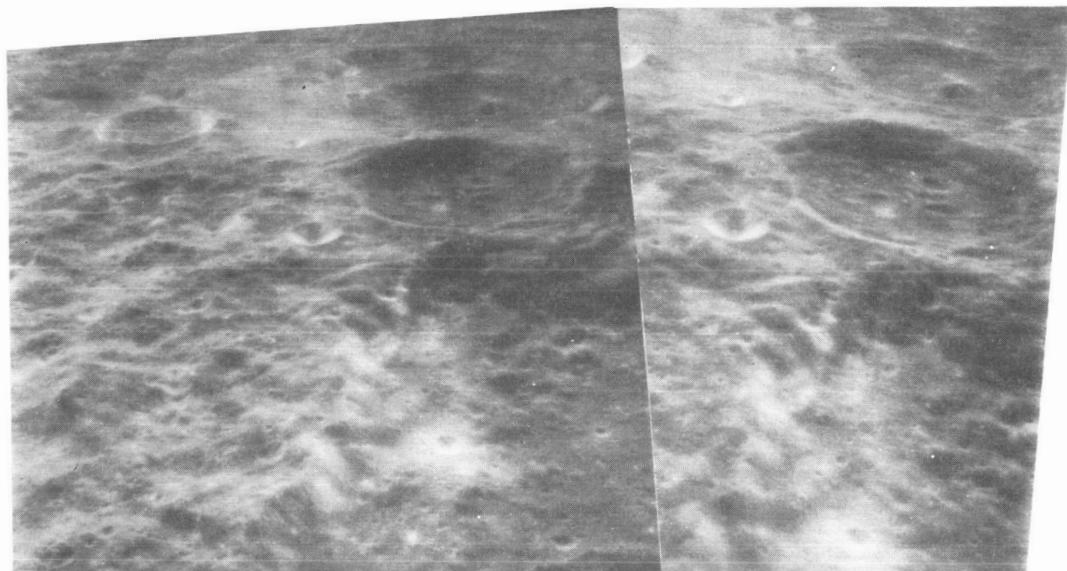


FIG. 13-B. 6513/6514: CRATERS IX, 216, AND 217.

Stereo Pair Frame Nos.: 6551/6550\* (Figure 14)

Film Type: Color S.O. 368

Principal Point: Latitude - 3.0°N  
Longitude - 85.0°E

Sun Angle: High

Subject: This stereo pair, arranged from two photos taken looking west from a point in the northeastern portion of Mare Smythii, is an excellent example of the value of stereo viewing. For example, observe the small "twin peaks" on the floor of Mare Smythii, just "under" earth, and in front of the "mountain range" in the background. Using stereoscopic viewing, it becomes quite obvious that the "twin peaks" are actually a dome structure in the floor of a fairly large crater, whose diameter is approximately 15 n.mi. The "mountain range" is an area of hummocks and craters trending northeast, adjacent to craters Schubert B and Schubert.

Stereo Pair Frame Nos.: 6610/6608

Film Type: Color S.O. 368

Principal Point: Latitude - 7.0°N  
Longitude - 178.0°W

Sun Angle: Low

Subject: The stereo qualities of this pair are poor (if one attempts to view the entire area of overlap of the two photos) because of the large tilt angle differences. However, by arranging the two photos stereographically several times, in slightly different orientations, one may view incremental areas, and get a good impression of areas typical of the rugged lunar farside. Craters 308 and 309 are partially visible in these photos, which were taken near Target of Opportunity 15.

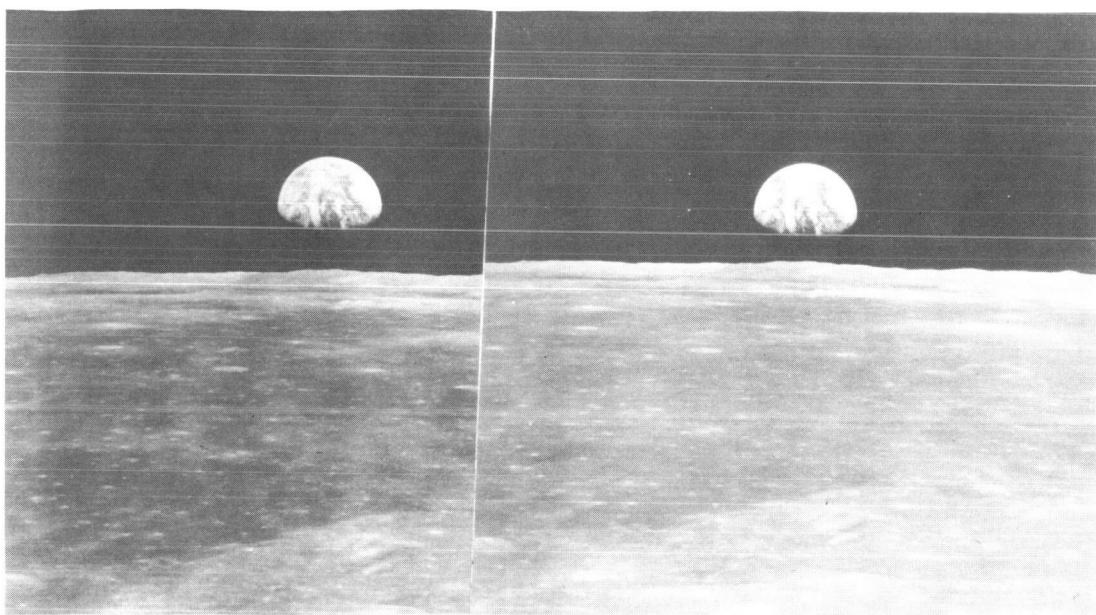


FIG. 14. 6551/6550: MARE SMYTHII.

#### IV. FEASIBILITY DEMONSTRATION OF USING PHOTOGRAHMETRIC TECHNIQUES FOR MAKING LUNAR ELEVATION MEASUREMENTS

Because of the vast amount of high quality lunar photography available as a result of the Apollo flights, it appeared to be worthwhile to investigate available methods for measuring elevations, or differences in elevation between two points, on lunar photographs taken from the LM and CSM. Information about elevation differences, slope angles, topographical contour plots, etc., will be essential during analytical studies, mission planning, and traverse planning activities associated with the Lunar Roving Vehicle (LRV), manned and unmanned, programs.

Photogrammetry is by no means a new science. In fact, references to the use of aerial photography (taken from balloons) for early topographical mapping, which date back well over 100 years, have been found by the author.

Today, a large array of sophisticated photogrammetric equipment, some of which is coupled with electronic computers and plotters, is available to photogrammetric engineers. Many federal and state agencies, as well as universities and private companies, have used various types of this equipment for years.

The simpler types of equipment, which are, of course, less expensive and more readily available, have a serious drawback. The stereo photos which are to be used to obtain topographical measurements of a given area must be "vertical,"\* or very nearly so. If they are not "vertical" (i.e., the plane of the photo is not horizontal), then the basic photogrammetric principles, which have been mathematically derived for vertical photos, do not hold true. It should be noted, however, that certain correction procedures have been devised for manually calculating the effects on photographic scale of small tilt angles, and elevation changes (due to image displacement). However, these are very time-consuming procedures, and arithmetic errors can easily be introduced.

On the other hand, some of the more exotic photogrammetric equipment can be operated and programmed to accept photographs which are tilted, or have slightly different scales, etc., and can correct internally for these discrepancies, and print out or plot the desired information, such as elevations, contours, slopes, etc.

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\* Vertical aerial photographs are those taken from a camera whose optical axis is kept in a truly vertical position, while the exposure is made.

It is quite likely that photographic missions of future Apollo flights will include provisions for some vertical photographs of the lunar surface, specifically of the lunar exploration sites, and proposed LRV traverse routes. Accordingly, it was decided to determine the feasibility of using locally available equipment for making photogrammetric analyses, so that when appropriate lunar photography becomes available, it can be fully exploited for the benefit of the LRV program, and other lunar surface exploration and experimentation programs that may follow.

Equipment available locally was (1) a "Stereo Comparagraph," Model No. 121 GE, manufactured by Gordon Enterprises, 5362 North Cahuenga Boulevard, North Hollywood, California, 91601, and (2) a drawing board and miscellaneous standard items of drafting equipment. Illustrative examples (using Apollo 10 stereograms) of the application of the "Engineer's Scale" method and the "Stereo Comparagraph" method are included in this report. However, both methods are based upon the "Theory of Parallax." Accordingly, a short treatment of this principle is included at this point. Before proceeding with the examples, please see Figure 15.

From figure 15, one can readily see how two adjacent (vertical) photographs, arranged stereoscopically (represented by "edges" EG and HK), can be used to calculate elevations of various ground points, as long as the images of the points can be seen on the photographs. In Figure 15, "h" represents the elevation of the point in question above the chosen datum plane; "f" represents the focal length of the camera; "H" represents the altitude of the aircraft or spacecraft which is taking the pictures; and "B" is the distance between points A and C where the photographs were taken. The direction of station D as seen from points A and C is different. This difference in direction of station D is defined as its "parallax." Theoretically, the parallax for station D is the angle  $\theta$ . Now, if one constructs a line at point A parallel to CD, the angle EAG is then equal to  $\theta$ . Since it is more convenient to use linear quantities scaled from photographs than the parallax angle, use of the linear intercept EFG is the generally accepted practice. EFG is then equal to FG plus JH. If one chooses to use the "air base" AC as the x-axis of the two stereoscopically arranged photographs, then the parallax "p," according to the generally accepted practice, is the algebraic addition of the two x-coordinates (FG, HJ). Triangles ACD and EAG are similar. Therefore, one is able to state that

$$\frac{f}{EG} = \frac{f}{p} = \frac{(H - h)}{B}$$

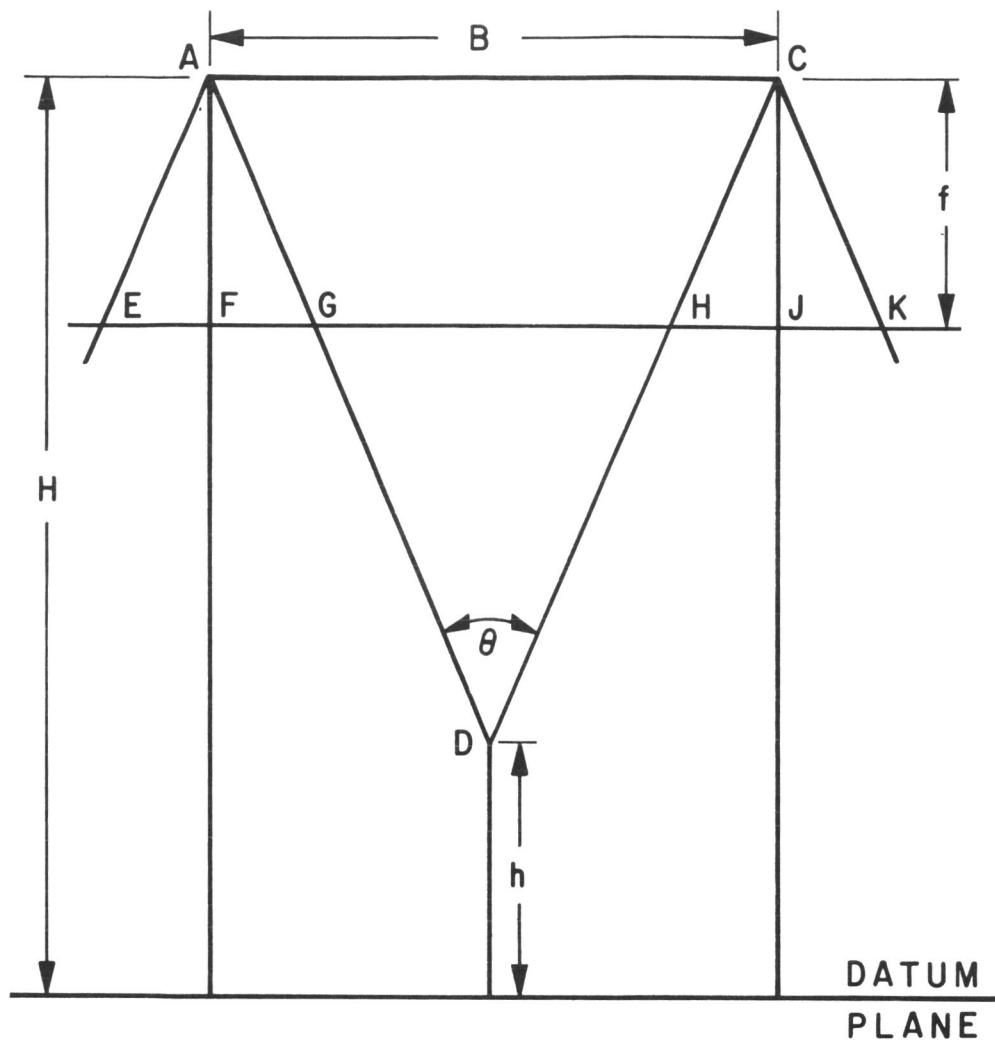


FIG. 15. PARALLAX GEOMETRY.

where  $p$  equals the linear parallax for station D. Then,

$$h = H - \frac{Bf}{p} .$$

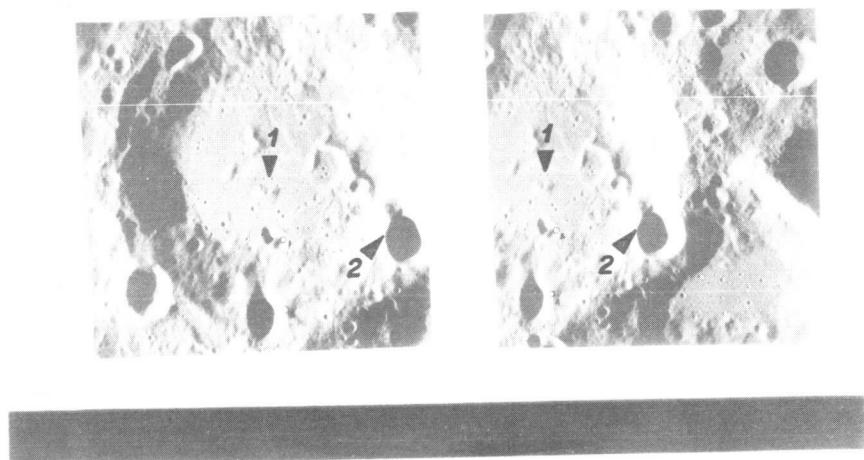
This resulting equation, called the parallax equation, can then be used to calculate station elevations of stations visible on the two photographs of a stereogram, provided one has knowledge of the distance between the two stations from which the photographs were taken, the elevation of the aircraft or spacecraft which took the pictures, the focal length of the camera used, and some means for measuring the parallax from the photographs.

Now that the basic principle of parallax has been illustrated, the "Engineer's Scale" method and the "Stereo Comparagraph" method for measuring parallax, and hence elevations, will be demonstrated. To the author's knowledge, there are no photographs in the Apollo 10 or Apollo 11 groups which are within 3 degrees of being vertical. However, as mentioned earlier, some truly vertical photographs are expected to result from future Apollo missions, and it appears wise to be prepared for this occurrence. However, for illustrative purposes, photographs were chosen which "appeared" approximately vertical.

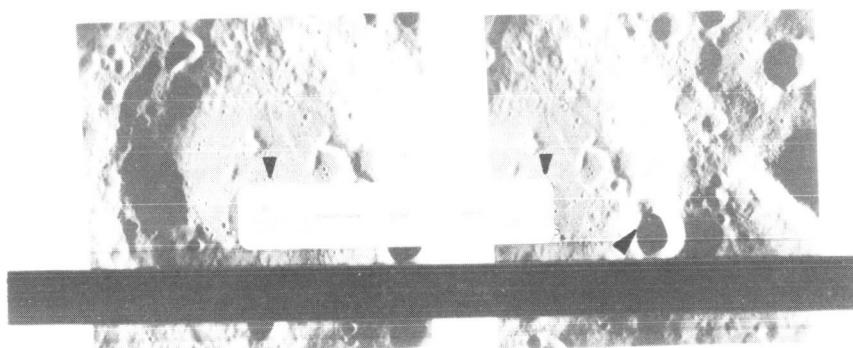
#### A. Engineer's Scale Method

Apollo 10 photographs 4067 and 4066 (see figure 16-A), which show crater 225, at  $0.4^{\circ}\text{N}$  and  $172.8^{\circ}\text{E}$ , were chosen for this illustration. It was known beforehand that these photographs have a tilt angle of approximately 22 degrees; however, the procedures outlined below, which were used for this feasibility demonstration, are based on the assumption that the photographs are vertical:

- (1) Locate and mark the center of each photograph.
- (2) Locate the point on the left photograph which corresponds to the center of the right photograph, and mark it. (This is called the right photograph's conjugate center.)
- (3) Locate the point on the right photograph which corresponds to the center of the left photograph, and mark it. (This is called the left photograph's conjugate center.)
- (4) Orient the photographs so that the lines of centers coincide and the images are a proper distance apart for good stereoscopic vision.



*A*



*B*

*FIG. 16-A&B. ENGINEER'S SCALE METHOD.*

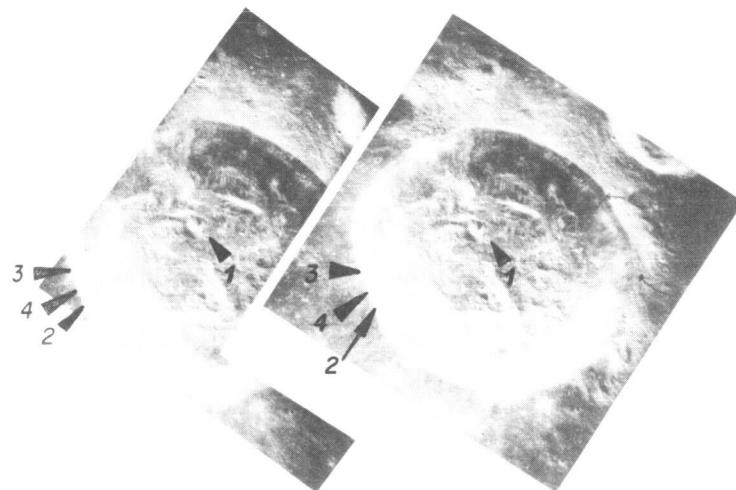
- (5) Through the center of each photograph, erect a perpendicular to the line of centers, these being called the y-axes of this pair of photographs.
- (6) The x-coordinates, of points for which elevations are desired, are then measured on each photograph with a finely divided engineer's scale (see figure 16-B).
- (7) The parallax is then determined from the algebraic difference of the two x-coordinates; i.e.,  $p = x_a - x_b$  where  $x_a$  = x-coordinate of left photograph and  $x_b$  = x-coordinate of the right photograph for the particular point location being considered.

Figure 16-A shows these two photographs arranged on a drawing board with the line of centers rotated slightly down to the left so that it is parallel to the T-square, thereby facilitating accurate measurements of x-coordinates.

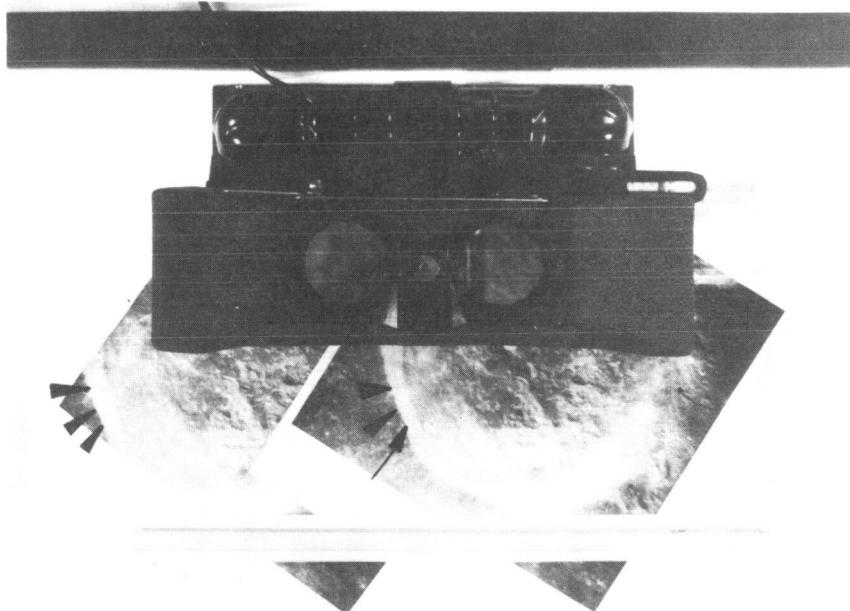
Let us suppose we wanted to determine the difference in elevation between point 1, a point on the floor of the crater between two small impact craters (marked by a black arrow in the center of the left photograph of Figure 16-A), and point 2, a point on the left side of a fairly prominent crater on the lower right quadrant of crater 225 (also marked by a black arrow). The x-coordinates would be measured from the center of each photograph for point 1 and subtracted to obtain the parallax of point 1. Parallax for point 2 would be determined the same way. Then using the parallax equation, the elevation of the two points can be determined, thereby allowing us to calculate the difference in elevation. The other terms in the parallax equation are readily available from flight data, i.e.,  $H$ , the flying height,  $B$ , the distance between exposure stations, and  $f$ , the camera's focal length. For the sake of completeness, the values of parallax for points 1 and 2, corrected for scale differences between photograph and negative, were  $p_1 = 17.6$  mm and  $p_2 = 21.2$  mm. This experiment demonstrated that parallax can be determined quite easily from the types of photographs taken, and that the resolution qualities of the photographs are satisfactory for this purpose.

#### B. Stereo-Comparagraph Method

The photographs chosen for this experiment were also from Apollo 10 photography numbers 4199 and 4200, which show a large crater south of crater 216, coordinates  $0.2^\circ\text{N}$  and  $133.2^\circ\text{E}$  (see Figure 17-A). The photograph alignment procedures for preparing the photographs for "Stereo-Comparagraph" viewing are identical to steps 1 through 4, described previously for the "engineer's scale" method, and are not repeated here.



**A**



**B**

**FIG. 17-A & B. STEREO -  
COMPARAGRAPH METHOD.**

After the lines of centers of the two photographs are made to coincide, the photographs are fastened to a piece of bristol board, and the entire assembly is positioned so that the line of centers is made parallel to the T-square of a drawing board. The bristol board is then fastened to the drawing board, as in figure 17-A. Figure 17-b shows the Stereo-Comparagraph positioned on the drawing board, with its base aligned parallel to the T-square, and hence parallel to the line of centers, sometimes called the "air base." At this point, one is ready to start reading parallax values directly from the micrometer on the right-hand side of the instrument, as shown in Figure 17-B. The micrometer is then adjusted so that the measuring mark dots on the meniscus lenses appear to be fused together (coincident) over a given point on the crater rim, e.g., points 2, 3, and 4 marked on the rim on the left side of the crater. The micrometer is then read, and the value noted. The instrument is then moved over the photographs to a point one chooses to consider the datum level, e.g., a point in the floor of the crater, making certain that the final position of the instrument base is parallel to the stereoscopic base (air base). The micrometer is then readjusted over the datum point to make the measuring mark dots appear to be fused together again. A micrometer reading is then taken, and the difference in the two readings is the parallax value for the point originally measured on the crater rim. Then, using the parallax equation, one can calculate the elevation of the point on the rim. Even though these photographs were tilted 15 degrees, consistent parallax measurements were obtained, again demonstrating that the photograph quality, resolution, and clarity would be amenable to good instrument measurements if the photographs were truly vertical. On this pair of photographs, the datum point (point 1) was chosen just below the rosette-shaped crater in the floor of the large crater, just above the center. Parallax readings for points 2, 3, and 4 relative to point 1 (the datum) were 4.70, 4.99, and 4.98 mm, respectively. With the Stereo-Comparagraph, one can also plot contour lines of a photographed area, provided the two photographs in the stereogram are vertical (within 3 degrees), and that their scales are very nearly equal.

## V. SELECTED SINGLE LUNAR PHOTOGRAPHS

Seventeen single photographs were selected for inclusion in this report to show a variety of the types of lunar terrain photographed by the Apollo 11 astronauts, which could prove valuable in future lunar surface mission planning. Objects included in this series of single photographs, and for which photographic interpretations are provided, are craters, rilles, mare areas, rough areas, and chain craters. Photograph frame numbers, object locations, and photographic interpretations are included.

SELECTED SINGLE LUNAR PHOTOGRAPHS FROM THE APOLLO 11 MISSION

Photograph Frame No.: 5433 (Figure 18-A)

Film Type: Color S.O. 368

Principal Point: Latitude - 4.0°N Sun Angle: High  
Longitude - 146.0°E

Subject: Crater 218, on the lunar farside, is shown. Located on the eastern perimeter of Basin IX, its diameter is approximately 57 n.mi., rim to rim, measured in an east-west direction. Crater 218 has a dome in its center, and is surrounded by craters of various ages [4]. The photograph shows the crater as viewed from the east.

Photograph Frame No.: 5437 (Figure 18-B)

Film Type: Color S.O. 368

Principal Point: Latitude - 0.2°N Sun Angle: Low  
Longitude - 24.5°E

Subject: This photograph, tilted approximately 60° to the west, provides some coverage of the area east of "Tranquillity Base," Hypatia Rilles, and "Boot Hill" [1]. The large crater in the lower right is Maskelyne, and Torricelli C is near the left margin, center. The picture was taken from the northeast.

Photograph Frame No.: 5438 (Figure 18-C)

Film Type: Color S.O. 368 Sun Angle: Semi-darkness

Subject: The rille structures shown are possibly in western Mare Tranquillitatis.

Photograph Frame No.: 5466 (Figure 18-D)

Film Type: Black and White - 3400

Principal Point: Latitude - 17.5°S Sun Angle: Medium  
Longitude - 173.0°E

Subject: This large crater, named "Washington" in the Rand-McNally Lunar Globe Index, is approximately 70 n.mi. in diameter (rim to rim) in the east-west direction. When viewed from the left corner, photograph 5466 is tilted approximately 65° to the south. Of interest to the lunar mission and experiment planners are the large, smooth mare area contained within the crater and the dome and hills. A bright Copernican crater, approximately 20 n.mi. in diameter, rim to rim in the north-south direction, is visible on the north rim of crater Washington (numbered 307 on ACIC charts). On this mission, crater Washington was classified as Target of Opportunity (T.O.) #19.

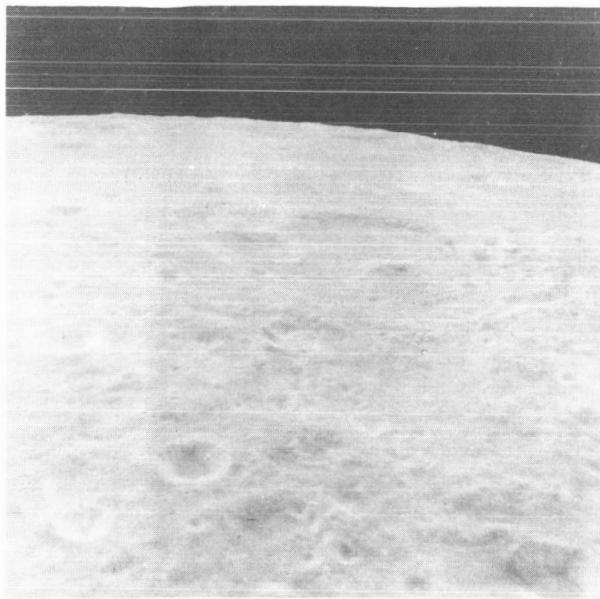


FIG. 18-A. 5433:  
CRATER 218.

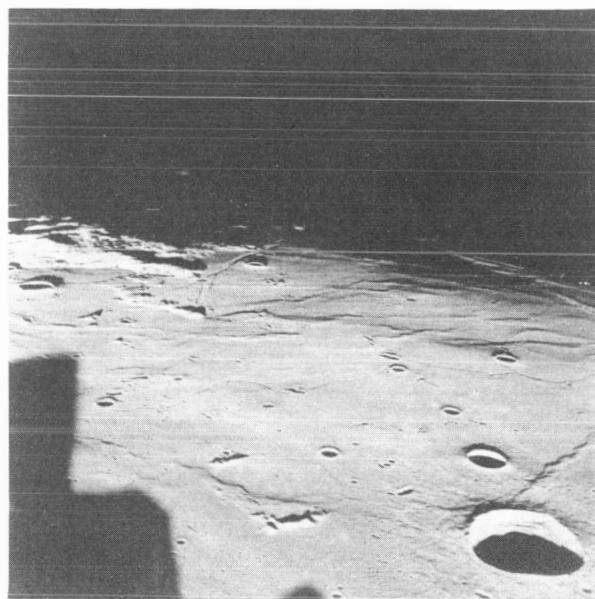


FIG. 18-B. 5437: SOUTH-  
WESTERN MARE  
TRANQUILLITATIS.



FIG. 18-C. 5438: WESTERN  
MARE TRAN-  
QUILLITATIS.

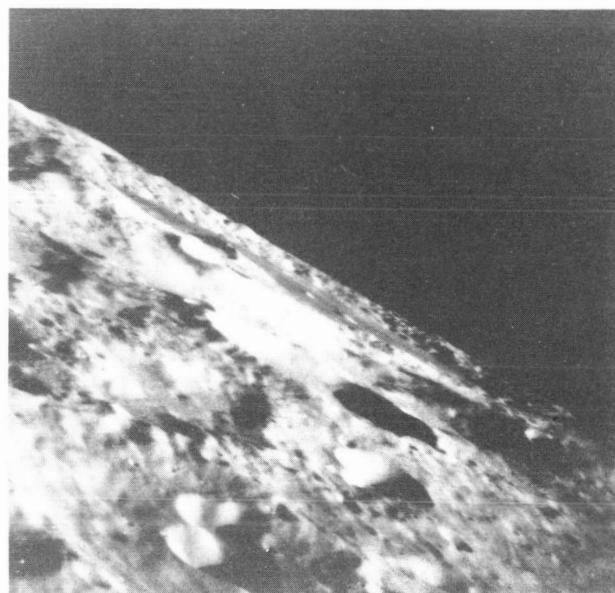


FIG. 18-D. 5566: CRATER  
"WASHINGTON".

Photograph Frame No.: 5567 (Figure 19-A)

Film Type: Black and White - 3400

Principal Point: Latitude - 12.0°S Sun Angle: Medium  
Longitude - 159.5°E

Subject: This crater, numbered 302, landmark data check point 8-2 for the Apollo 11 mission, is viewed in the photograph from the northeast; the photograph's tilt angle is approximately 65° to the southwest. Crater 302's diameter is approximately 75 n.mi., rim to rim, in the east-west direction. It has a central dome or peak, but its floor, unlike that of crater Washington discussed in the previous interpretation, is marked by numerous small craters of various sizes and ages. Notice the prominent terraces on the southern wall of the crater.

Photograph Frame No.: 5568 (Figure 19-B)

Film Type: Black and White - 3400

Principal Point: Latitude - 7.0°S Sun Angle: Medium  
Longitude - 173.0°E

Subject: This photograph, taken from the north-northeast, shows part of a crater chain trending toward crater Washington. This type of formation is possibly indicative of a sub-surface fissure. An earth analog of this crater chain is a group of cinder cones aligned along a fissure in the Cascade Mountains of Oregon, in the vicinity of Mount Jefferson.

Photograph Frame No.: 5571 (Figure 19-C)

Film Type: Black and White - 3400

Principal Point: Latitude - 11.5°S Sun Angle: Medium  
Longitude - 160.5°E

Subject: Another view of crater 302, this photograph was taken from a more northerly direction than was 5567, and thus provides a better longitudinal view of the crater's central cone and terraced structures on the south wall. The tilt angle of this photograph is about  $65^{\circ}$  to the south when viewed from the lower right-hand corner.

Photograph Frame No.: 5582 (Figure 19-D)

Film Type: Black and White - 3400

Principal Point: Latitude - 6.0°S Sun Angle: Medium  
Longitude - 173.0°E

Subject: This view shows the very rough terrain between craters 305 and 308 on the lunar farside. It was taken from a point farther west than was photograph 5568. On close examination, the crater chain of photograph 5568 can be seen on this photograph, just to the right of center. The approximate scale of this photograph is 1:1,174,600, while that of 5568 is 1:830,000 [2].

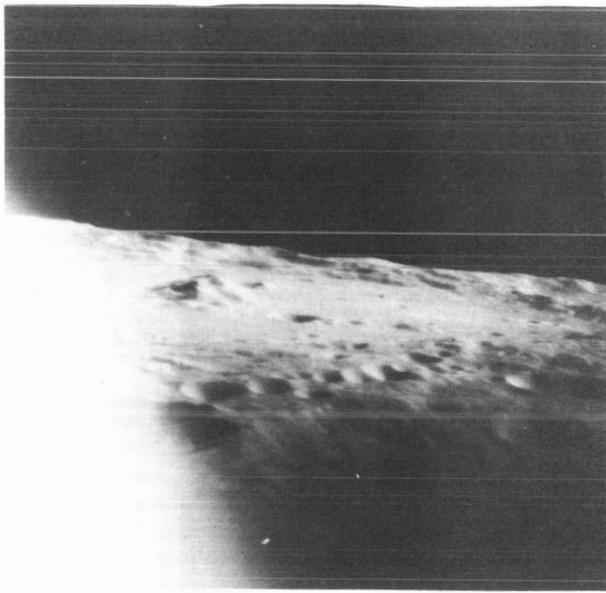


FIG. 19-A. 5567:  
CRATER 302.



FIG. 19-B. 5568: CHAIN  
OF CRATERS.



FIG. 19-C. 5571:  
CRATER 302.

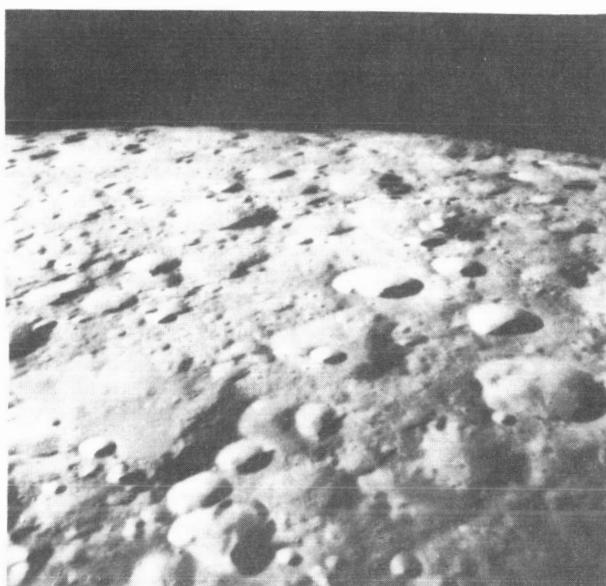


FIG. 19-D. 5582: TERRAIN  
BETWEEN CRATERS  
305 AND 308.

Photograph Frame No.: 5589 (Figure 20-A)  
Film Type: Black and White - 3400  
Principal Point: Latitude - 4.0°S Sun Angle: Medium  
Longitude - 152.0°E

Subject: Crater 297 (diameter approximately 63 n.mi.) shows a good contrast of relative ages of lunar craters. The bright Copernican crater on the rim closest to the viewer is the newest and freshest; the small sharp-rimmed crater (diameter  $\approx$  5.5 n.mi.) to the left of 297's central peak or dome, could be classified in the Eratosthenian (middle) Age, and crater 297 itself, with its eroded rim and slumped inner walls, could be classified Pre-Eratosthenian, or relatively the oldest. Notice the fairly large crater in the lower right-hand corner of the photograph, with the small crater on the left side of its rim. Which do you think is the older of the two?

Photograph Frame No.: 5602 (Figure 20-B)  
Film Type: Black and White - 3400  
Principal Point: Latitude - 2.0°S Sun Angle: Medium  
Longitude - 46.5°E

Subject: This is a good picture of Messier "A" (formerly called crater W. H. Pickering) in Mare Fecunditatis. A stereogram of this crater is shown in stereo pair 6305/6304, Figure 11-B. Photograph 5602, a view from the north-northeast, is tilted approximately 40° to the southwest.

Photograph Frame No.: 6151 (Figure 20-C)  
Film Type: Black and White - 3400  
Principal Point: Latitude - 6.5°S Sun Angle: Low  
Longitude - 180.0°W

Subject: This photograph shows the eastern half of crater 308. See also stereo pair 5563/5562 (Figure 5-A) for a stereo view of the southern portion, and Figure 33 for a mosaic construction. Crater 308's diameter is approximately 48 n.mi. in the east-to-west direction.

Photograph Frame No.: 6179 (Figure 20-D)  
Film Type: Black and White - 3400  
Subject: This picture of the solar corona was taken from the CSM while on a near circular lunar equatorial orbit.



FIG. 20-A. 5589:  
CRATER 297.

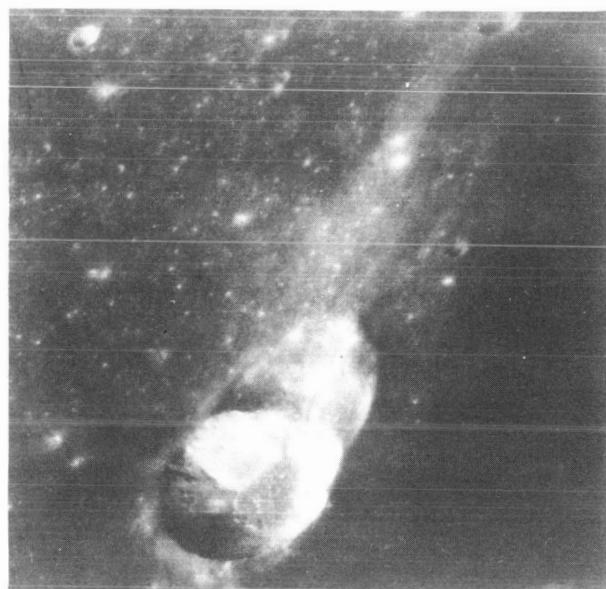


FIG. 20-B. 5602: CRATER  
MESSIER A.



FIG. 20-C. 6151: CRATER  
308 - EASTERN  
HALF.

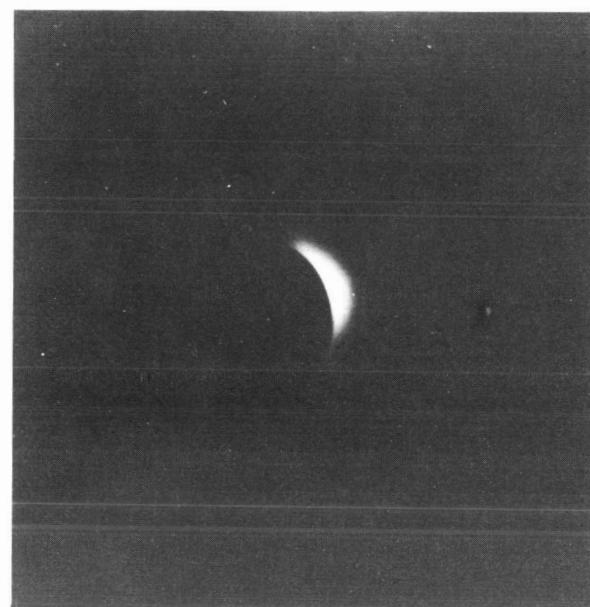


FIG. 20-D. 6179:  
SOLAR CORONA.

Photograph Frame No.: 6217

(Figure 21-A)

Film Type: Black and White - 3400

Principal Point: Latitude - 9.0°S  
Longitude - 62.0°E

Sun Angle: Medium

Subject: This is a picture of crater Langrenus, when viewed from the northeast. This crater is approximately 65 n.mi. in diameter. The photograph's tilt angle is about 60° to the southwest.

Photograph Frame No.: 6231

(Figure 21-B)

Film Type: Black and White - 3400

Principal Point: Latitude - 12.0°S  
Longitude - 42.5°E

Sun Angle: Low

Subject: This photograph provides a very clear view of the northeastern quadrant of Mare Tranquillitatis. The camera was pointed toward the northwest when the picture was taken. Crater Taruntius, whose depth from the top of the rim to the bottom of the floor is 2950 feet, is in the foreground. Crater Cauchy, the prominent impact crater to the left of the center, is enclosed by Cauchy Rille on the right and Rupes Rille on the left. The large flooded crater, to the right of center and just in front of the craters on the horizon, is Maraldi D. To its right is Macrobius A on the western reaches of Palus Somnii (sleeping marsh).

Photograph Frame No.: 6356

(Figure 21-C)

Film Type: Black and White - 3400

Principal Point: Latitude - 9.5°N  
Longitude - 103.0°E

Sun Angle: High

Subject: This view, looking toward the north-northeast, shows craters 198, 197, and 200, in that order, from foreground to background. The photograph's tilt angle is approximately 60° to the north. On the west rim of the crater 198, one can observe a Copernican crater, portions of which have slid over into crater 198. Crater 198 is approximately 33 n.mi. in diameter.

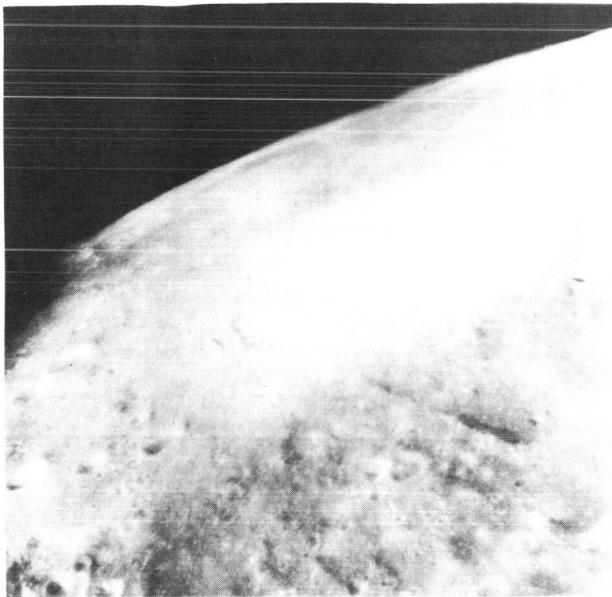


FIG. 21-A. 6217: CRATER LANGRENUS.

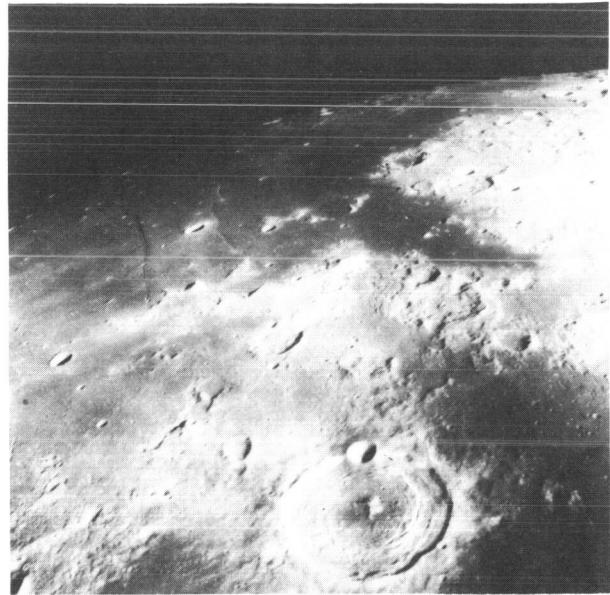


FIG. 21-B. 6231: NORTHEAST MARE TRANQUILLITATIS.

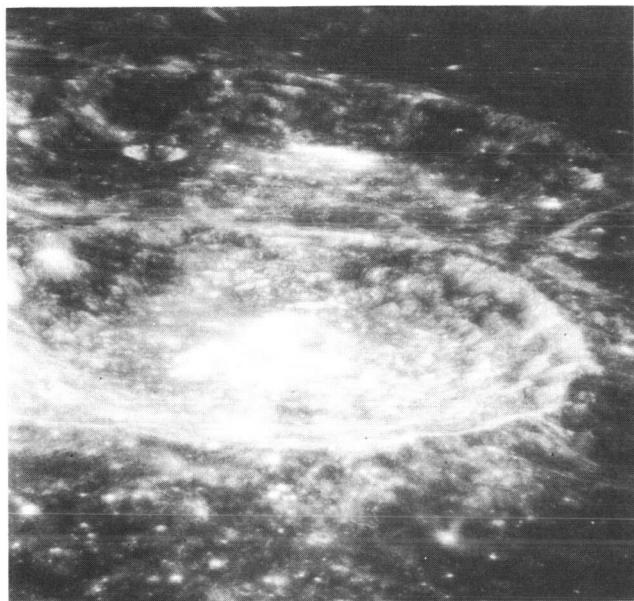


FIG. 21-C. 6356: CRATERS 198, 197, AND 200.

Photograph Frame No.: 6449

(Figure 22-A)

Film Type: Black and White - 3400

Principal Point: Latitude - 6.0°N  
Longitude - 120.5°E

Sun Angle: High

Subject: Crater 211 is relatively bright, and may be of Copernican age. Also known as Target of Opportunity 46, this crater has a large "U" shaped central cone. The Apollo 10 astronauts also photographed this formation, which can be seen in stereogram in reference 1, page 10.

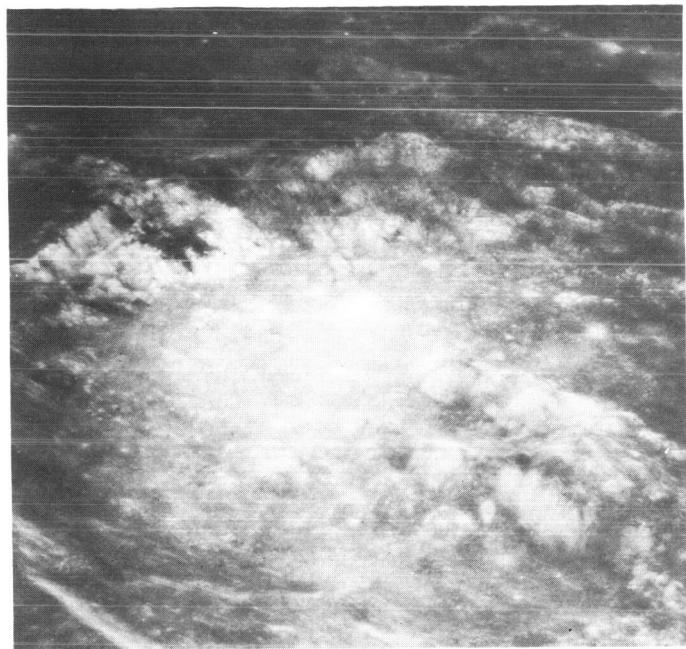
Photograph Frame No.: 6472

(Figure 22-B)

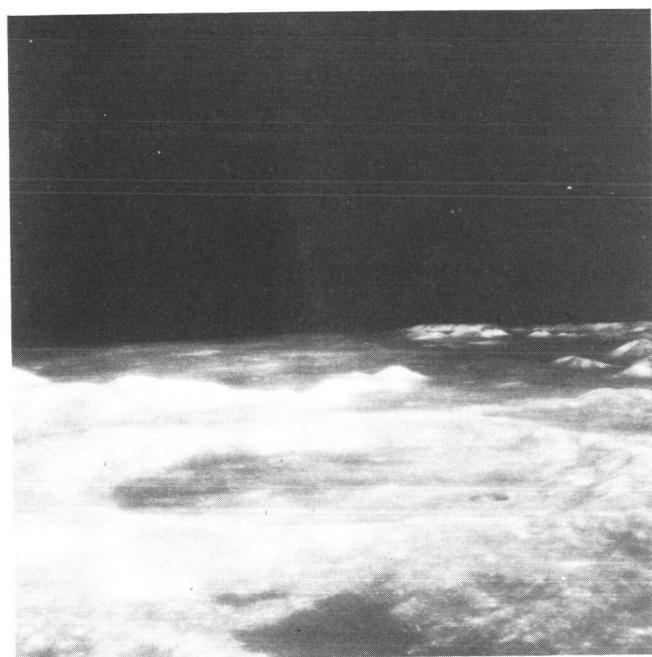
Film Type: Black and White - 3400

Sun Angle: High

Subject: This northwesterly view shows Crater Condorcet on the south-eastern quadrant of Mare Crisium. The large mountain to the left of center is Promontorium Agarum. The angle of tilt of this photograph is approximately 70° to the northwest. Crater Condorcet is approximately 42 nautical miles in diameter.



*FIG. 22-A. 6449:  
CRATER 211.*

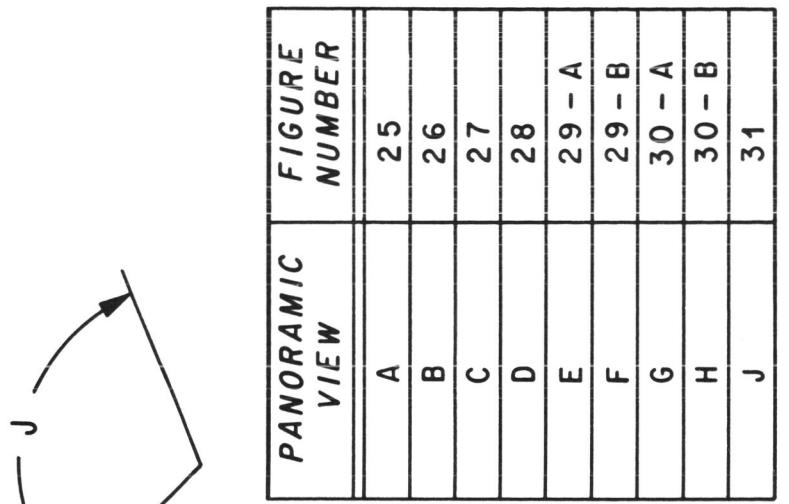
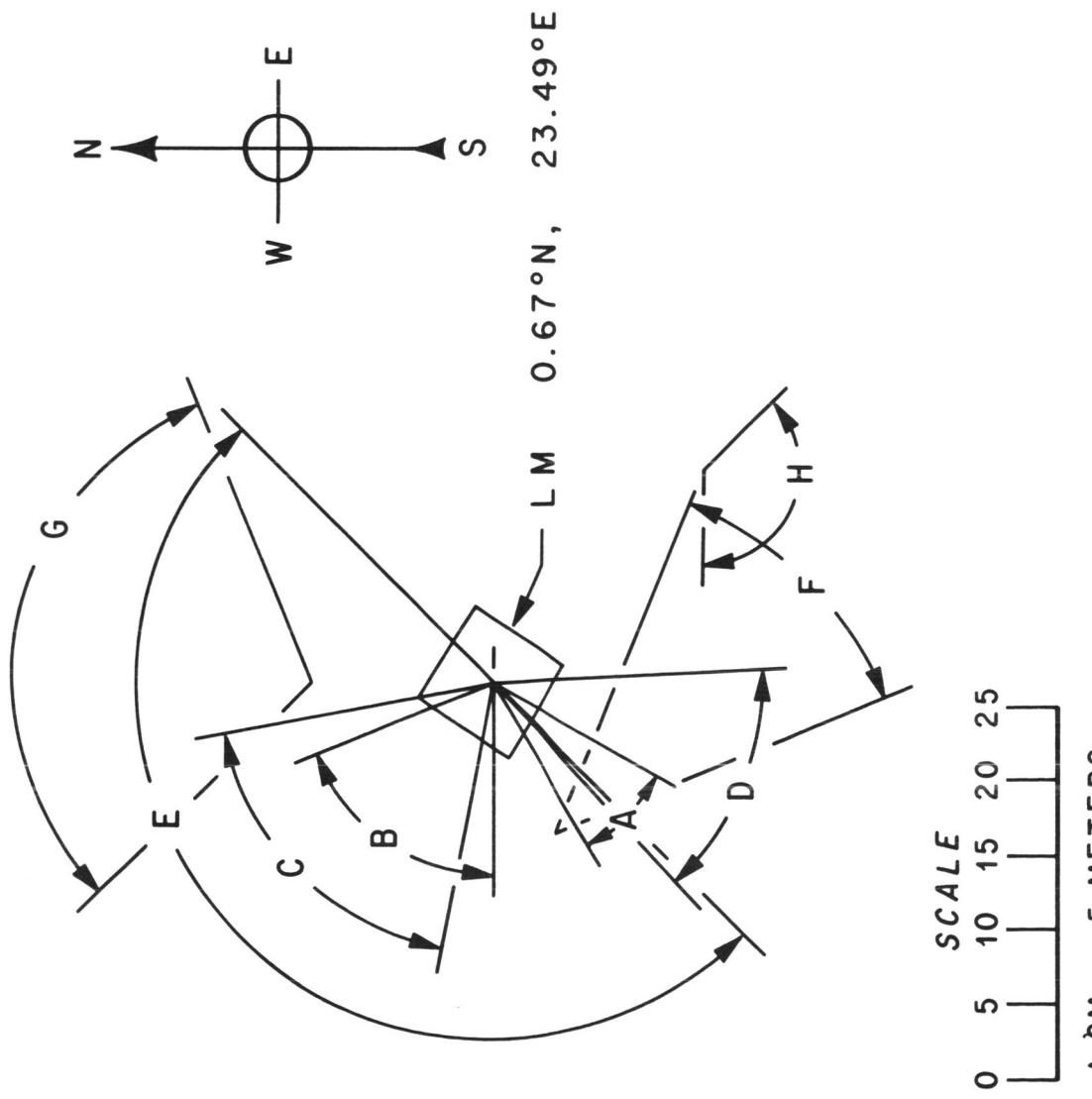


*FIG. 22-B. 6472: CRATER  
CONDORCET.*

## VI. PHOTOGRAPHIC CONSTRUCTIONS

Nine panoramic views, one strip sequence, and one mosaic construction are included in this section. The panoramic views are shown in Figures 25 through 31, and Figure 23 provides a key to their location, relative to the LM location. Figure 24 shows the geographical location of the Apollo 11 landing site. In most cases, the component photographs of the panoramic views were fitted together to provide the best possible pictorial representation of the terrain in the foreground, and not in the background or horizon area. These were prepared in this manner in order to give the most accurate representation possible of the nearest topographical features that can be seen the best, e.g., rocks, crater rims, hummocky terrain, etc. This accounts for the discontinuity on the horizon between some of the component photographs.

Figure 32 provides a sequence of photographs of an area along the equator extending westward from Craters Sabine, Ritter, and Schmidt. Figure 33 is a mosaic construction of crater 308 on the lunar farside.



SEE - AERO - Y



FIG. 24. GEOGRAPHICAL LOCATION OF THE APOLLO 11 LANDING SITE.

PANORAMIC VIEWS, STRIP SEQUENCE, AND MOSAIC VIEW  
CONSTRUCTED FROM APOLLO 11 PHOTOGRAPHS

Figure Number: 25

Component Photographs: 5449/5450

Subject: This is a view to the southwest from the LM window; the LM thruster is in the foreground (Tranquillity Base).

FIG. 25. 5449/5450: SOUTHWEST OF LM.

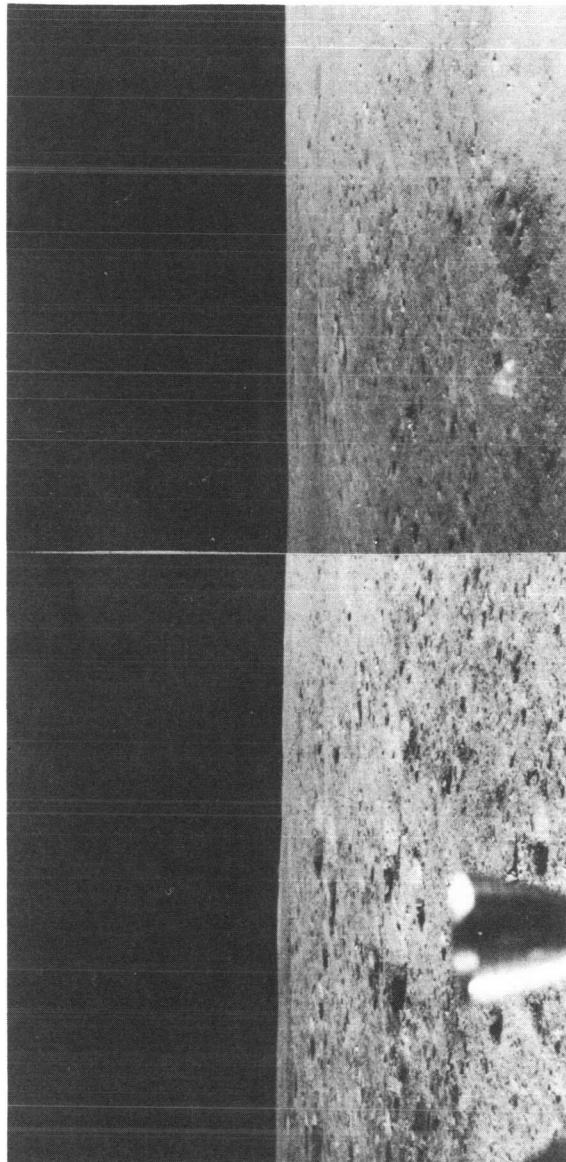


Figure Number: 26

Component Photographs: 5454/5455/5456/5457/5458

Subject: This is a view ranging from the west (left end of series), to the north-northwest (right end of series), from the LM window, before the flag and TV camera were emplaced.

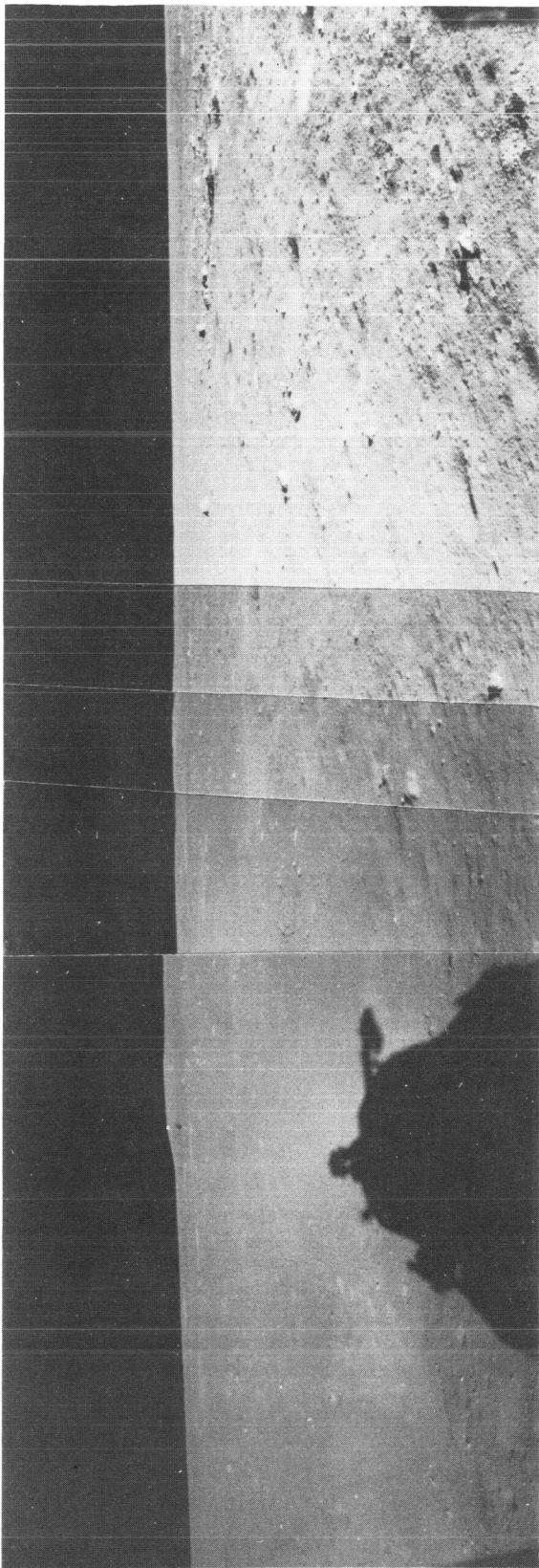


FIG. 26. 5454 / 5455 / 5456 / 5457 / 5458:  
WEST TO NORTH - ●ORTHWEST  
OF LN.

Figure Number: 27

Component Photographs: 5465/5466/5467/5468/5469

Subject: This is a northwesterly view at Tranquillity Base with the rock field in background, and the TV camera and the flag in the foreground.

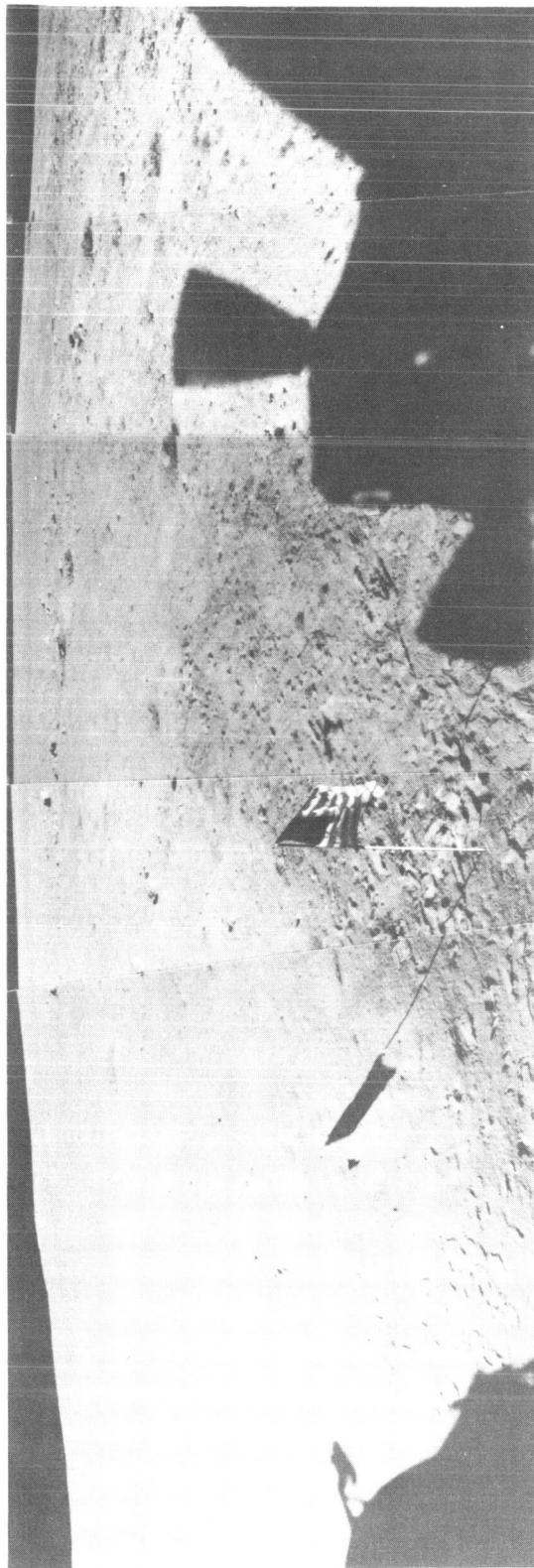


FIG. 27. 5465/5466/5467/5468/5469: NORTHWEST  
TO NORTH-NORTHWEST OF LM.

Figure Number: 28

Component Photographs: 5759/5760/5761/5762

Subject: This is a southwesterly view from the LM, showing the double crater and shadow of the LM on the lunar surface.

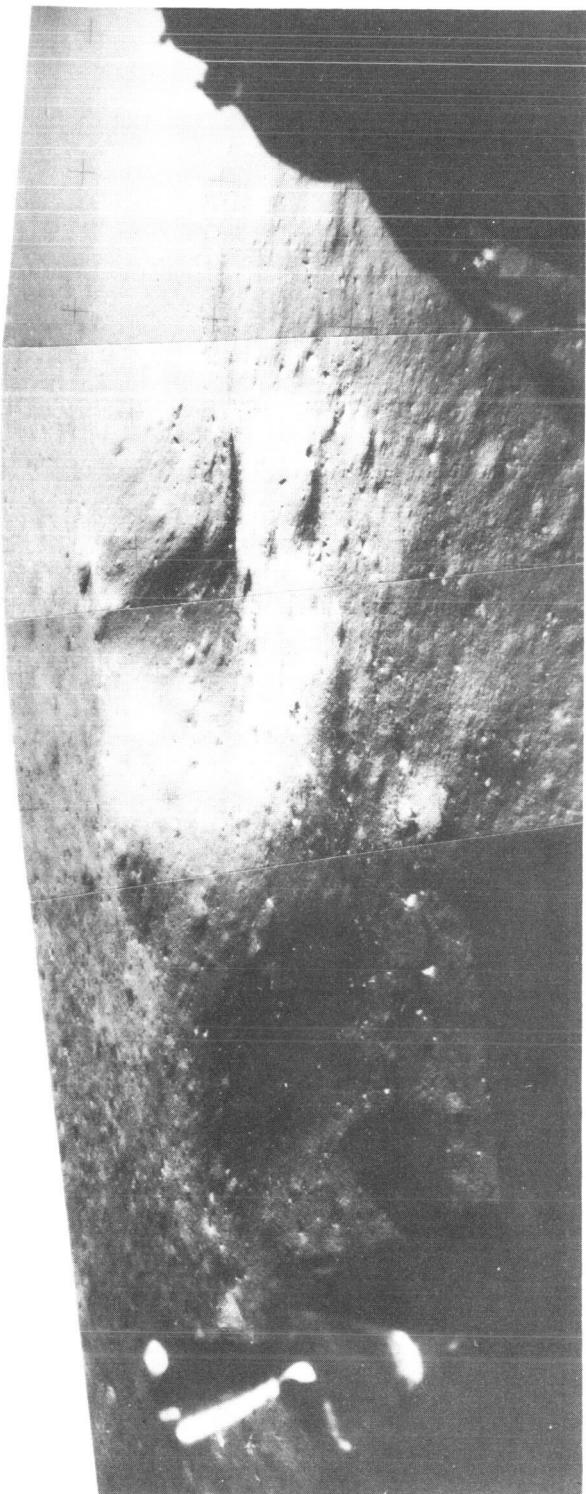


FIG. 28. 5759 / 5760 / 5761 / 5762: SOUTH-SOUTHWEST OF LM.

Figure Number: 29-A

Component Photographs: 5853/5854/5855/5856/5857/5858

Subject: This composite view, ranging from a southwesterly direction on the left to a northeasterly direction on the right, gives a good idea of the types of terrain in the vicinity of Tranquillity Base. In the center of this panoramic view, some fairly large boulders can be seen. This series was taken from a point close to the western-most footpad of the LM.

Figure Number: 29-B

Component Photographs: 5888/5889/5890/5891

Subject: The photographs in this panoramic scene were taken from a point approximately 11 meters to the west-southwest of the LM at Tranquillity Base. The direction of view varies from east-southeast on the left end to south-southeast on the right. Astronaut Aldrin evidently stood on the rim of a crater, approximately 12 meters in diameter, while taking this series of pictures.

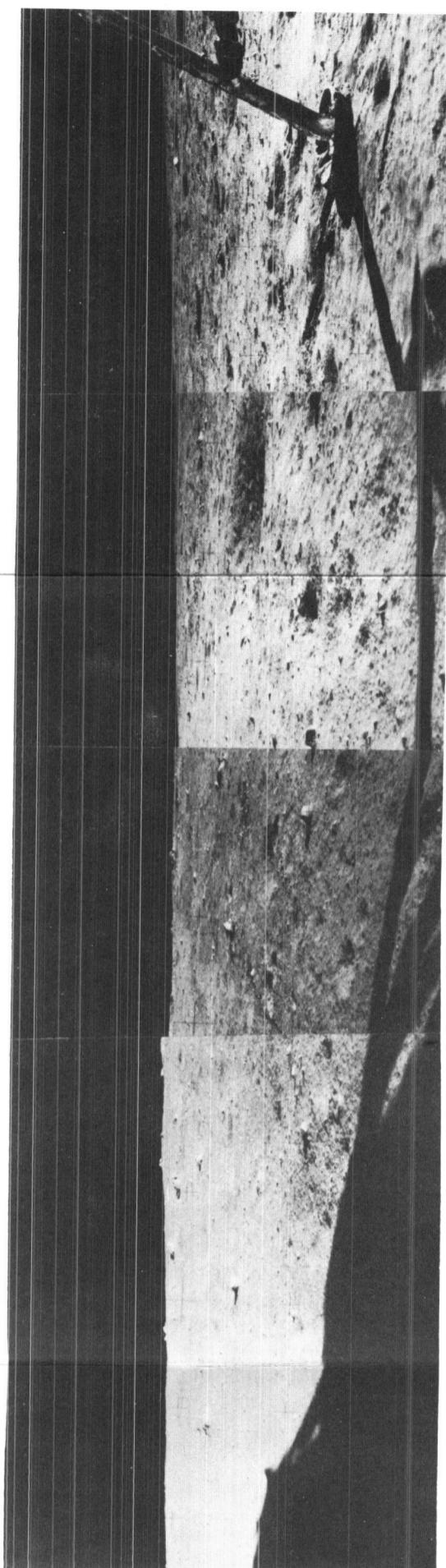


FIG. 29-A. 5853/5854/5855/5856/5857/5858: SOUTHWEST TO NORTHEAST OF L.M.

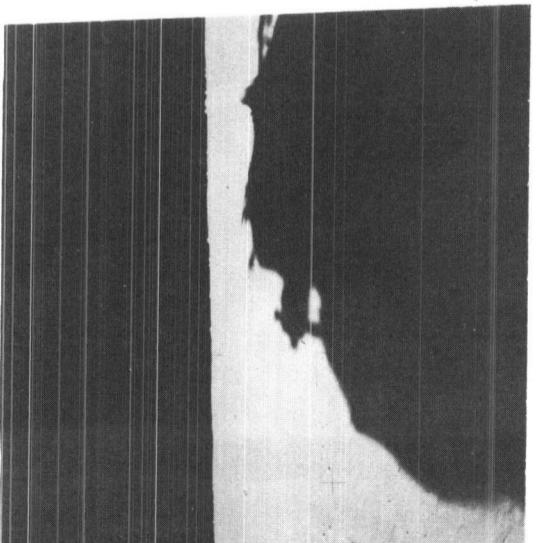


FIG. 29-A. 5853/5854/5855/5856/5857/5858: SOUTHWEST TO NORTHEAST OF L.M.



FIG. 29-B. 5888/5889/5890/5891: SOUTHEASTERLY VIEW  
FROM POINT 11 METERS WEST-SOUTHWEST OF L.M.

Figure Number: 30-A

Component Photographs: 5907/5908/5909/5910/5911

Subject: This panoramic series was taken from a point approximately 12 meters north of the LM; the direction of view ranges from northwest on the left end, through north in the center, to east-northeast on the right end. The TV camera is shown approximately 12 meters to the northwest of the point from which the pictures were taken. The soil material on the rim of the crater in the immediate foreground appears to be quite loose and granular.

Figure Number: 30-B

Component Photographs: 5937/5938/5939/5940/5941

Subject: This series of photographs was taken by Astronaut Armstrong from a point approximately 20 meters southeast of the LM. Direction of view ranges from southeast at the left end of the panoramic series, through south, to west at the right end of the series. The area is fairly well covered with rocks and small boulders.

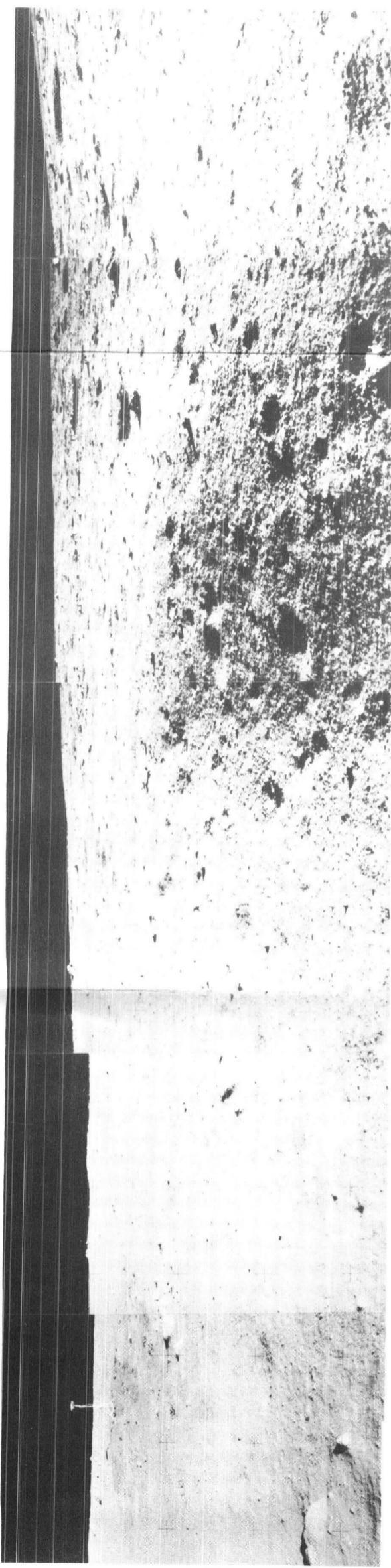


FIG. 30-A. 5907/5908/5909/5910/5911: NORTHWEST TO EAST - NORTHEAST  
VIEW FROM POINT 12 METERS NORTH OF LM.

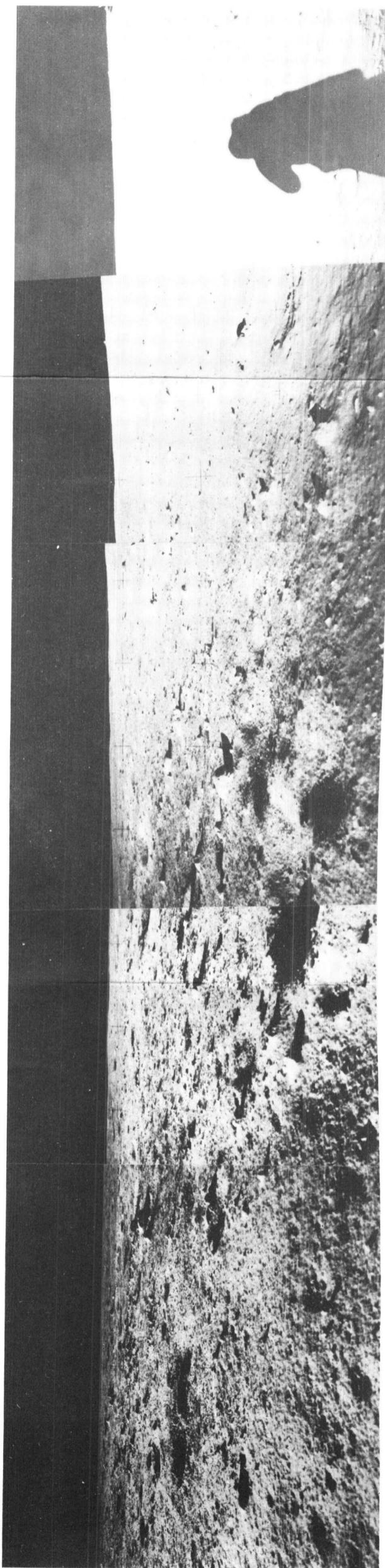


FIG. 30-B. 5937/5938/5939/5940/5941: SOUTHEAST TO WEST VIEW  
FROM POINT 20 METERS SOUTHEAST OF LM.

Figure Number: 31

Component Photographs: 5955/5956/5957/5958/5960

Subject: This series was taken from the rim of a 35-meter-diameter crater by Astronaut Armstrong, who was standing at a point approximately 62 meters to the east of the LM. The direction of view ranges from northwest at the left end of the series, through north, to east-northeast on the right end of the series. In the foreground, one can observe the stereo close-up camera designed by the Eastman Kodak Company for photographing the fine structure of lunar soils before the samples were dug for return to earth. The camera was also designed for photographing larger rocks or fissures, or the junction of interesting formations. When extended for use, the camera is 14.5 inches high, and the handle telescopes to a height of 32 inches above the surface to be photographed. The camera holds the film approximately 10 inches from the surface; the resulting photographs will enable scientists to see particles smaller than 2/1000ths of an inch, and to identify the shape of particles as small as 4/1000ths of an inch. Each exposure yields a stereo pair of the lunar surface three inches square. The camera lenses are arranged such that a 9-degree stereo angle is provided. The camera has a fixed shutter speed of 1/100th of a second, a fixed effective aperture of f/22.6, and is equipped with an electronic flash mechanism which provides a 200 microsecond flash.

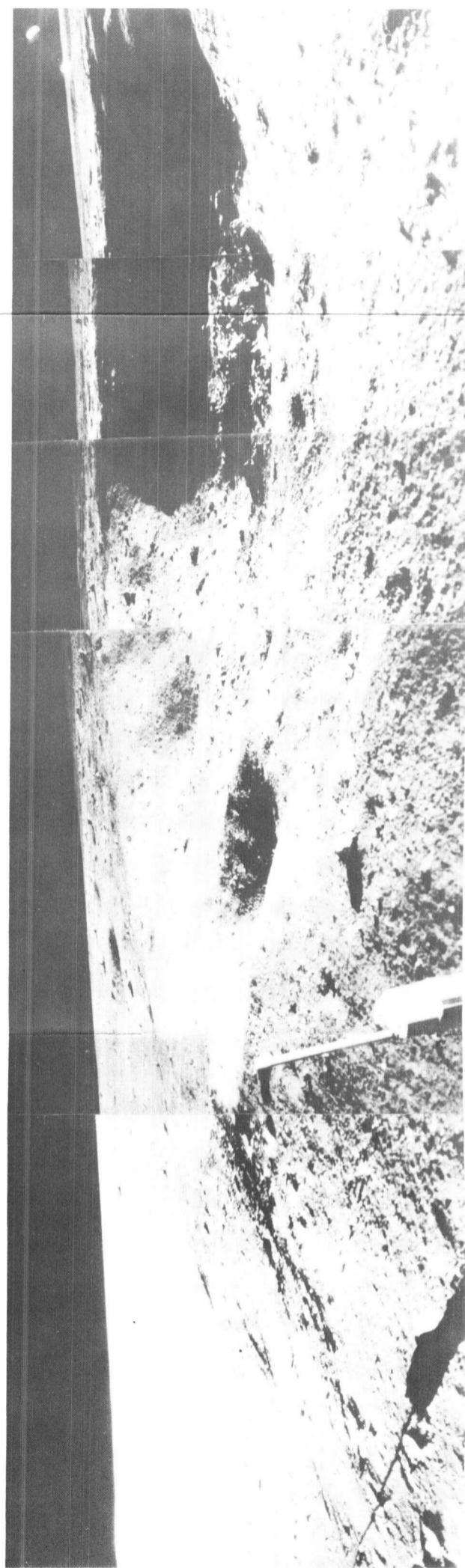


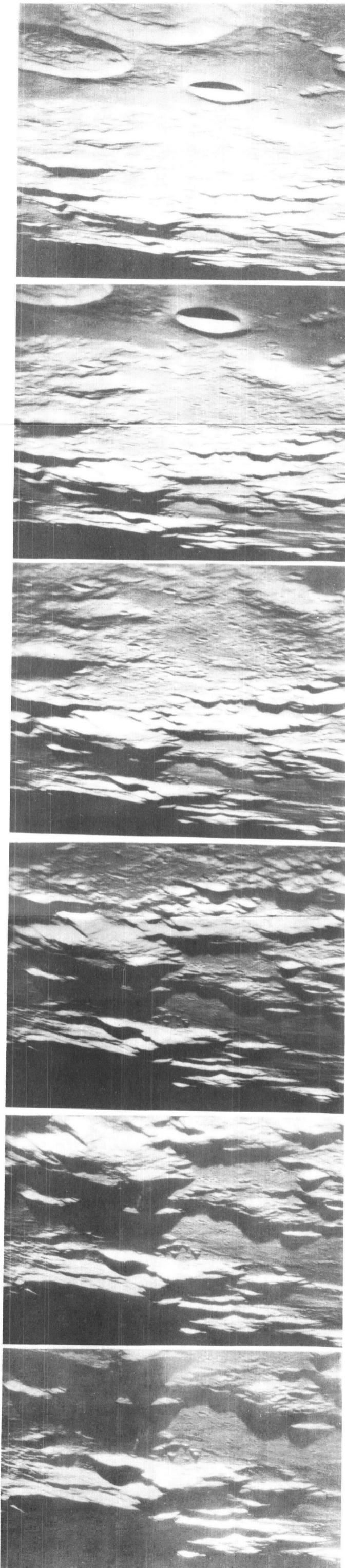
FIG. 31. 5955/5956/5957/5958/5960: NORTHWEST TO EAST-NORTHEAST VIEW  
FROM POINT 62 METERS EAST OF LM.

Figure Number: 32

Component Photographs: 6123/6124/6125/6127/6128/6129

Subject: This "strip" or series of photographs was taken starting over crater Sabine (approximately  $20^{\circ}$ E and  $3^{\circ}$ N) and continued in a westerly direction parallel to the equator. Photograph 6123 shows Craters Sabine and Ritter (the two large ones) and Crater Schmidt. Photograph 6125 was the start of a series called T.O. (Target of Opportunity) 132, whose purpose was to show an "area of elongated crater cones and irregular domes of probable volcanic origin" [6]. The locus of the principal points of the photographs shown, extends from  $1.0^{\circ}$ N,  $17.0^{\circ}$ E (photograph 6123) to  $0.5^{\circ}$ N,  $11.0^{\circ}$ E. Forward overlap is about 85 percent between each succeeding photograph. Tilt angles of the photographs vary from 65 to 70 degrees.

FIG. 32. 6123/6124/6125/6127/6128/6129: STRIP SEQUENCE OF TARGET OF OPPORTUNITY 132.



6123

6124

6125

6127

6128

6129

Figure Number: 33

Component Photographs: 6151/6152/6153

Subject: This mosaic, which was constructed from the three photographs listed above, presents an oblique view of crater 308, approximately 5°S, 179°E. The scale of photograph 6152 is approximately 27 percent greater than that of 6151 and 6153; also, the tilt angle of 6152 is approximately 65° to the southeast; whereas, that of 6151 and 6153 is approximately 55° to the south. These two differences account for the discontinuity on the crater rim between photographs 6152 and 6153.

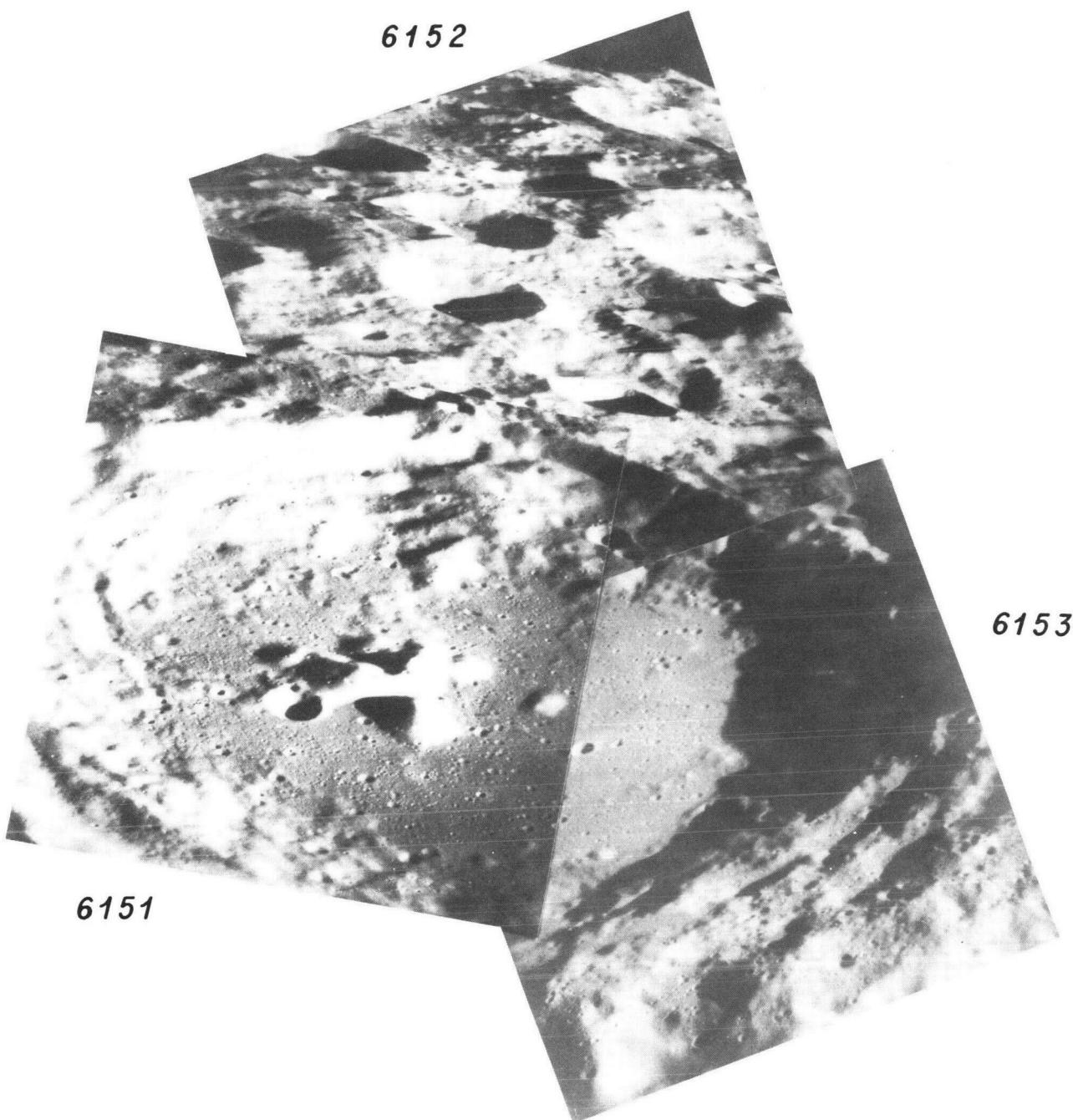


FIG. 33. 6151/6152/6153: MOSAIC  
OF CRATER 308.

#### SUMMARY REMARKS

There is no doubt that the pictorial information obtained by the Apollo astronauts will contribute much toward conducting realistic future mission planning. Use of the photography resulting from Apollo 11, as well as previous and future Apollo flights, should be fully exploited.

Scientists engaged in earth resources analyses should find that the earth photographs resulting from this mission, such as those shown in Figures 1-A, 1-B, 2-A, 2-B, and 3-A in this report, contain a vast amount of useful information.

Based upon photographic coverage of the terrain in and around the Tranquillity Base area, it is concluded that lunar roving vehicles can be maneuvered and operated safely and effectively in mare areas similar to the Tranquillity Base area, provided a reasonable amount of driver caution and route selection is exercised.

Analysis of photographs taken during future Apollo lunar surface activities will increase the confidence in lunar roving vehicle design, and will be helpful in preparing vehicle operating guidelines.

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APPROVAL

NASA TM X-64501

SOME PHOTOGRAPHIC RESULTS OF THE APOLLO 11 MISSION

by Paul A. Larsen

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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